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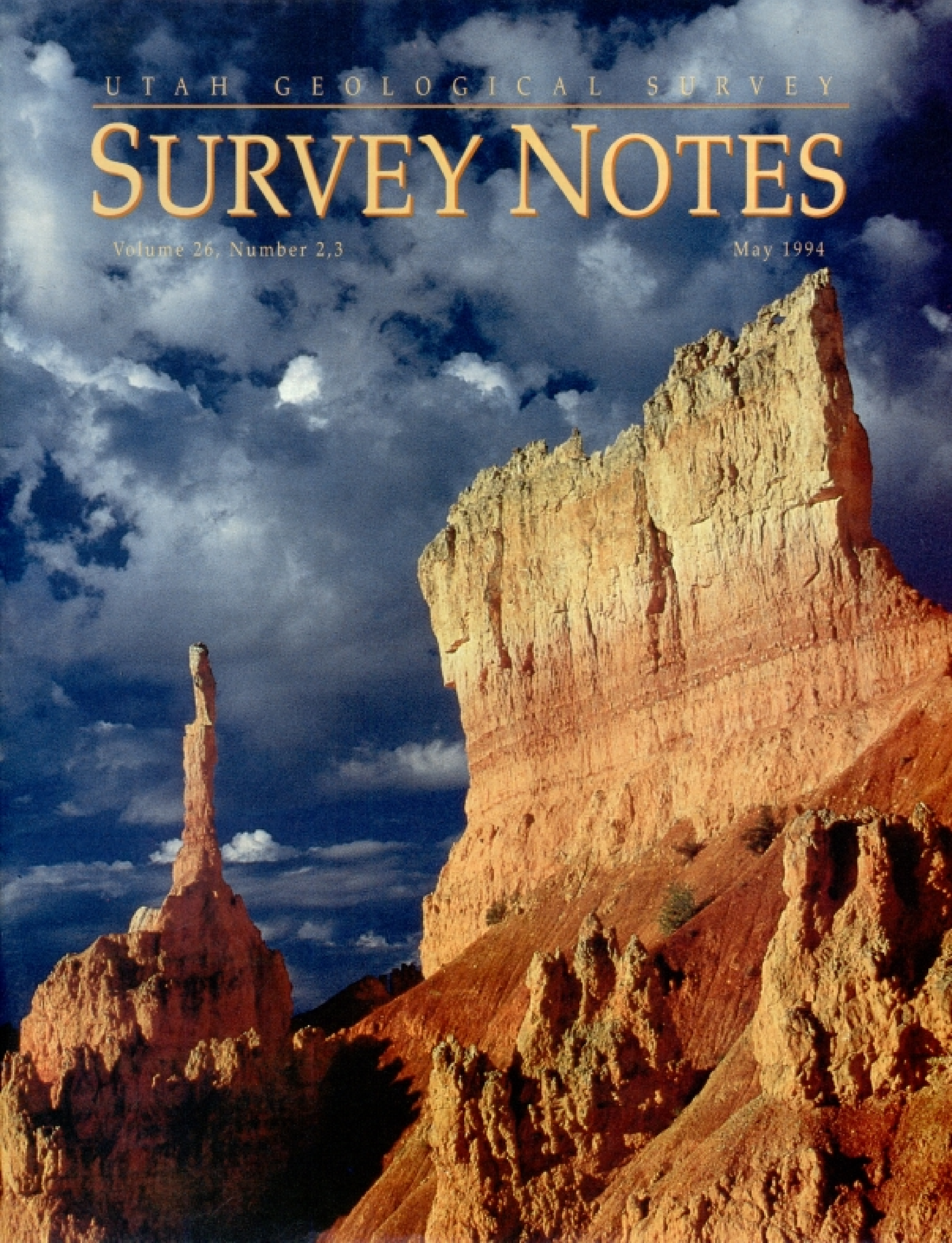

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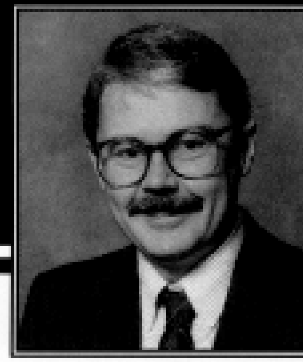
The Director's Perspective

by M. Lee Allison



In March of this year, the UGS Board gathered to recognize the contributions of three former Board members who stepped down at the ends of their terms last year. Sam Quigley and Larry Reaveley each served eight years, while Ken Poulson spent a record 16 years on the UGS Board. Few people, inside or out of the UGS, know how the ideas and operation of the Board, and particularly these three, contribute to the success and focus of the Survey. We also bid farewell to Lynnelle Eckels, who is relocating to Texas after serving just over one (very dynamic!) year on the Board.

The seven members of the UGS Board are appointed by the Governor for staggered four-year terms. Four represent aspects of the energy and minerals industries, one the civil engineering community, one the business-scientific community, and one the general public. In addition, the Director of the Utah Division of State Lands and Forestry serves as an ex-officio member.

Every Governor has listened to the advice of those constituency groups before making a nomination to the Board, which must be approved by the Utah Senate. Governor Leavitt's transition team met to review the UGS Board when he took office, and reported back that the UGS Board was one of the most impressive and outstanding boards in the state. Quite a compliment when you realize there are over 200 such boards and panels and that many of them are peopled with the movers and shakers of the state.

The Board meets quarterly in an advisory capacity. Meetings seldom attract much public attention, and in contrast to those of some other state boards, are congenial, informative, and very effective. The Board is the guiding hand of the UGS philosophy and policy. Through its expertise, experience, and diversity, it ensures that the UGS is indeed serving the needs of the state's citizenry.

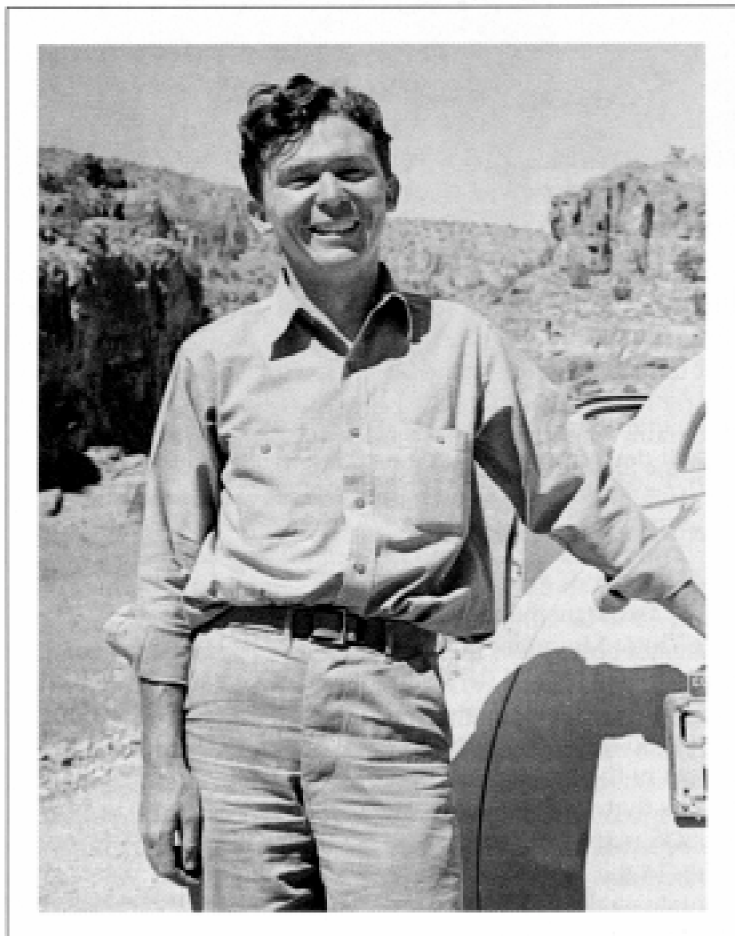
Occasionally, actions of the UGS have stirred controversy or concern to a part of the community. In some cases, the Board, through its position and reputation, has been able to clarify the situation and resolve the issue. Sometimes that has meant directing the UGS to change or reconsider our decisions. The Board also intervenes on the UGS' behalf with the Administration or Legislature when needed.

Overall the UGS Board has been and continues to be a major asset to accomplishing our mission, which is, fundamentally, to make Utah richer and safer: richer through prudent development of our natural resources; safer from the effects of geologic hazards. Without them, we would not be the dynamic agency that we are today.

Survey Notes is published three times yearly by Utah Geological Survey, 2363 South Foothill Drive, Salt Lake City, Utah 84109-1491; (801) 467-7970. The UGS inventories the geologic resources of the state, identifies its geologic hazards, disseminates information concerning Utah's geology, and advises policymakers on geologic issues. The UGS is a division of the Department of Natural Resources. Single copies of *Survey Notes* are distributed free of charge to residents within the United States and Canada. Reproduction is encouraged with recognition of source.

Hal Morris, "Utah Mapper"

by Fitz Davis

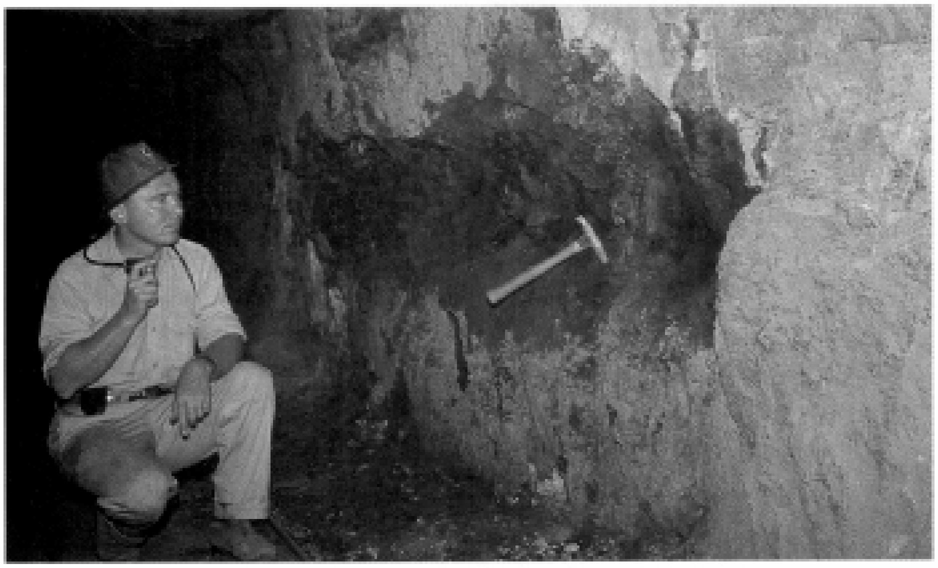


Hal, 1949, a young geologist in the Thomas Range, Juab County, Utah.

During his distinguished career with the U.S. Geological Survey (USGS), Hal T. Morris authored or co-authored 62 reports pertaining to the geology and mineral deposits in western Utah. Many of these reports contain excellent geologic maps, and some deal exclusively with the geology of a particular area. Highlights of his published mapping include the Richfield and Delta 2° quadrangles, ten 7.5-minute quadrangles, and maps for Cove Fort, southern Pine Valley, Milford, and east half of the Frisco quadrangle. Hal also wrote a significant structural paper, "Interrelations of thrust and transcurrent faults in the central Sevier orogenic belt near Leamington, Utah."

Hal will always be best known for his collaborations with Thomas S. Lovering in the geologic mapping, studies of hydrothermal alteration, studies of ore deposits, and the development of exploration techniques for blind-ore deposits in the East Tintic mining district. Their careful and accurate geologic mapping and geochemical studies pinpointed promising exploration targets that led to the following discoveries: (1) an ore body now associated with Burgin mine which grossed $177 million in production from 1963 to 1978 (chiefly zinc, lead, silver, gold, and copper); (2) the Trixie gold and copper ore body which had $25 million gross production from 1969 to 1979 (shut down in 1992); (3) the unmined Ballpark ore body, estimated by Kennecott Copper corporation to contain 37 million short tons of ore including 4.5 million ounces of silver, 1.5 million short tons of zinc, and 0.5 million short tons of lead; and (4) the Homansville mineralized area, estimated to contain ore bodies similar in tonnage and grade to those of the Trixie mine.

Hal worked with Tom Lovering in the East Tintic Mountains from 1947 to1951, from 1953 to 1954, and intermittently thereafter for a number of years. Their studies produced two monumental reports, USGS Professional Papers 361 (1961) and 1024 (1979), plus many spin-off reports published in scientific journals, Utah Geological Society guidebooks, and elsewhere. Some of their earlier reports attracted the attention of sever-



Hal examining the first ore cut in the Burgin mine in 1957. The ore exposed on the 1,050-foot level consisted of oxidized manganiferous lead and zinc minerals.

al major mining companies and eventually led to drilling exploration. Hal continued working full time in the district until 1957, after which he worked fairly regularly in the East Tintic Mountains, the West Tintic Mountains, the Sheeprock Mountains, and elsewhere in western Utah until his retirement in 1986.

In 1975, Hal produced another significant report, "Geologic map and sections of the Tintic Mountain quadrangle and adjacent part of the McIntyre quadrangle." The map and accompanying text describe an inferred major caldera in the central East Tintic Mountains that was indicated as a result of USGS mapping and volcanic studies in the area. This caldera contains a deep, partly delineated, porphyry copper-molybdenum deposit reported by Kennecott Copper Corporation to contain 150-400 million short tons of ore with 0.6-1 million tons of copper and 75-100 thousand tons of molybdenum, depending on the minimum cut-off values assigned. The field studies also resulted in the first definitive understanding of the volcanic history and petrology of the central East Tintic Mountains.

The Early Days

Hal was born in Salt Lake City, Utah, on October 24, 1920. In 1928, he and his family moved to Ogden, Utah, where he resided, except for military service, until 1947. Hal's introduction to geology was a half-year course taught in 1938 by Gordon Y. Croft at the newly completed Ogden High School. Convinced through this exposure to become a professional geologist, he enrolled at Weber College for two years where he was further encouraged by geology professors Walter R. Buss and Orlo E. Childs. In 1940, Hal transferred to the University of Utah. All went well until the outbreak of World War II. Three-and-a-half months after the attack on Pearl Harbor, having completed all the requirements for his B.S. degree, Hal enlisted in the U.S. Marine Corps. Within a few months, however, he was discharged for medical reasons and returned home. From July to August 1942, Hal worked at his first professional job as a geologist with the Utah Construction and Mining Company, then from August to October as a mineralogist with the U.S. Bureau of Mines in Salt Lake City.

"Hal would be halfway up a hill before I could get my backpack out of the vehicle."

That year he also married Elizabeth Jones in Ogden, Utah. One month later, Hal was inducted into the less persnickety U.S. Army, where he served for three years in the Chemical Warfare Service. He served his final months in the army service on the island of Saipan. Upon his return to Ogden, Hal was greeted not only by his wife, but by a nine-month-old son, who was born about the time Hal shipped out to the western Pacific.

Almost immediately after his discharge, Hal entered a Master's program at the University of Utah. Shortly thereafter, Professor Bronson F. Stringham introduced him to Tom Lovering, with whom Bronson had worked in the East Tintic mining district during 1944 and 1945. At this time, Lovering was single-handedly carrying out detailed studies there for the USGS, and he needed help. Tom and Hal quickly developed a close rapport and friendship, and Lovering later asked Hal to undertake some laboratory work for the East Tintic project. This work led to an invitation to serve as Lovering's field assistant during the summer months of 1946 and 1947, which Hal accepted. Hal finished his M.S. degree requirements in 1947 and wrote a thesis entitled, "The igneous rocks of the East Tintic mining district, Utah." That spring he successfully passed the civil-service examination for geologists and, shortly after graduation, was offered a permanent position with the Mineral Deposits Branch of the USGS. He was assigned full-time to the East Tintic project in October 1947.

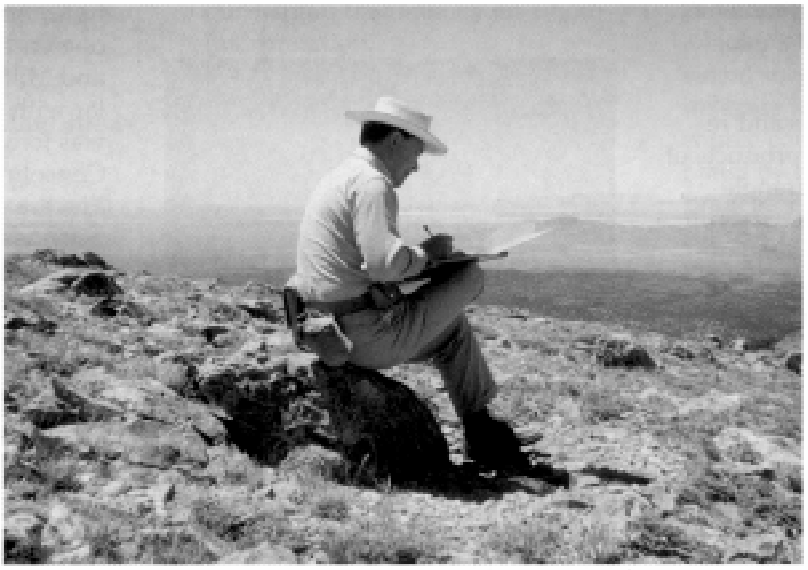
The Professional Years

In February 1951, Hal was asked to

to fill a temporary position on the staff of the USGS Mineral Deposits Branch in Washington, D.C. In the beginning, Hal assisted the Branch Chief and others in preparing answers to inquiries from budget analysts, U.S. Senators, Representatives, industry officials, and private citizens. Later, his duties were re-directed toward helping identify, evaluate, and select the numerous geologists who were hired by the USGS during the greatly expanded uranium investigations and defense-minerals programs of the 1950s. This task was essentially completed by June 1953 and Hal was scheduled to be reassigned to a new field project in Arizona. However, Lovering wanted assistance in completing the East Tintic study and demanded Hal's return to Utah. This was done and for an additional year Hal resumed his old position.

A few months after Hal returned to Utah, Lovering became deeply involved with administrative assignments and also became an international lecturer in economic geology, thus the East Tintic project languished. At this time, Hal established a new project which encompassed the main Tintic mining district and the greater part of the East Tintic Mountains. As part of this new project, Hal completed 1:24,000-scale geologic maps of the Eureka and Tintic Junction quadrangles. During this period, Hal and his family resided year-round in Eureka, Utah. He was mapping at the surface during the summer and fall months, and underground in the winter and spring in the last operating mines in the main Tintic district. This rather ideal arrangement for a geologic mapper changed in 1957, when Hal was assigned to the USGS regional center in Menlo Park, California. Reluctantly, Hal, his wife, and their three children (Dan, Kay, and Mark) left Utah for California.

Being stationed at a major geologic center offered many advantages, including laboratory support, drafting, typing, editing services, and especially the interactions with many bright and active colleagues. Some of these people also worked on projects in Utah, including Max Crittenden, Ralph Roberts, Martin Sorensen, Ed Tooker, William Gere, and others. Hal's duties at Menlo Park entailed some administrative responsibilities, and from 1960-1969, Hal served as the Pacific Coast Area representative for the Office of Economic Geology and concurrently as Supervisor of Wilderness Area Mineral Evaluations group of the same region. Fortunately, his principal responsibilities and activities for the first few years remained with the East Tintic Mountains project.


Hal mapping in the West Tintic Mountains in 1966. Desert Mountain is in the distance. Photo: Rudy Kopf.

In January 1962, during some difficult budget negotiations, an influential senator politely "inquired" if the supplemental appropriation requested by the USGS included funds for a project in the West Tintic mining district of the southern Sheeprock Mountains. Apparently such a field project had been repeatedly requested by one of the senator's more influential constituents. Naturally, the Survey agreed that it did, and inasmuch as Hal's assignment as project chief was also part of the package, Hal was ordered to immediately halt all field work on other projects and get to work on West Tintic. Hal complied, but at times was able to bootleg some map compilation and lab work on the various East Tintic studies.

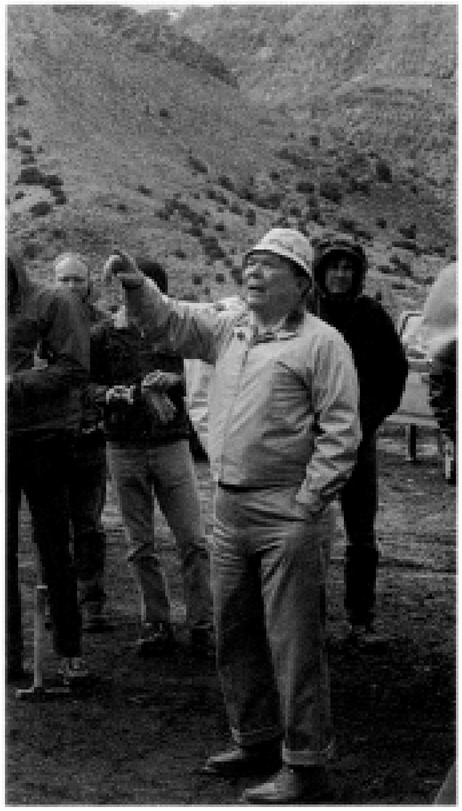
In March 1963, Hal was named Chief of the Branch of Base and Ferrous Metals at USGS, but continued to conduct field work and mineral evaluations in the Sheeprock and West Tintic Mountains, and intermittently map and compile reports on the East Tintic Mountains. In those days, the 20 or 25 projects of the Base and Ferrous Metals Branch were concentrated in the western states, but others were scattered from Georgia to Michigan and New England, and their supervision and personnel problems occupied a large part of Hal's time, (one branch member, for example, was hauled to jail in Virginia for trespassing!). After six years or so of administrative work and countless frustrations, Hal gave up his supervisory responsibilities and returned to project work, vowing to complete his sizeable backlog of uncompleted maps and reports.

The Modern Years

In 1972, Ed Tooker, who was Chief of the Office of Economic Geology at the USGS, asked Hal to compile a preliminary geologic map of the Delta 1° x 2° quadrangle with special emphasis on the potential mineral resources of the area. This test effort in part led Tooker to officially establish the Survey's Conterminous United States Mineral Assessment Program (CUSMAP). About this time, there was a resurgence of interest in mineral-resource evaluations, and inasmuch as Hal had been serving for a number of years as the USGS commodity specialist for lead and zinc, he participated in several evaluations.

Hal's last published maps and reports for the USGS were products of the Richfield 1° x 2° quadrangle CUSMAP project (1977-1983). Tom Steven, a colleague and friend of Hal's for 25 years, had agreed to take on the project as he had worked for some time in the volcanic terrains of the Tushar Mountains and adjacent plateaus in the eastern part of the quadrangle. Steven insisted, however, that he knew very little about the sedimentary rocks of the Great Basin and their structures, and requested that Hal share the project with him. Tom and Hal were fortunate to also obtain the collaboration of Pete Rowley, Myron G. Best, Skip Cunningham, Rudy Kopf, and several other highly capable geologists. The Richfield project probably holds the record for the production of spin-off maps and reports, but Hal was most proud of having completed for publication the several maps of the Frisco and Milford areas partly compiled by the late Dwight Lemmon, a USGS colleague who passed away before he had fully completed his field studies.

In 1983, Hal embarked on a compilation of geologic and geochemical data on the deep ore zones of the main Tintic district, which he had mapped from time to time during the 1940s and 1950s. No official publication resulting from this study was released, but much of the data have appeared in guidebooks and other short papers. Hal's final project for the USGS was a revision and recompilation of the geologic map of the Delta 1° x 2° quadrangle, which was selected in 1985 in the second tier of CUSMAP projects. After the preliminary map and an accompanying structural interpretation were released as USGS Open-File reports, Hal decided to retire and did so on May 31, 1986, having logged just a few months less than 39 years with the USGS.



Hal leading the 1986 introductory Delta CUSMAP field trip. Photo: Rob Yambrick.

Memories

Hal says of his career:

> It is a point of great personal satisfaction to me that I have worked with the finest group of geologists in the world and that my professional career has spanned what has to have been the best of all times for the science and practice of economic geology throughout the world. My professional life has bridged the gap between some of the great classical geologists and the current crop of whiz-kids with their emphasis on complex instruments and laboratory investigations, and it has been a very satisfactory experience. I had the pleasure and good fortune to have been acquainted with such famous geologists as Burt S. Butler, John M. Boutwell, Elliot Blackwelder, Frank Calkins, and Ralph J. Roberts, guru of the Carlin-type gold deposits, among many others. I have also treasured my relationships with many of the mine owners and operators in the Tintic and Milford areas, and in particular with the C.A. Fitch family, who was long associated with the Chief Consolidated Mining Company. The great majority of these people gave us full access to their properties and supported our work in countless other ways. The same is true of my contacts and collaborations with the many geologists and geophysicists, including a considerable number from countries throughout the world, who spent various periods of time in the Tintic and Frisco areas and the other nearby mining areas of Utah.

When a geologist works in the field or underground for many years, there are bound to be occasional harrowing experiences. Hal recalls:

> Probably the most dangerous situation that I experienced took place in the Apex Standard No. 2 mine in 1947. This mine had the reputation of being one of the hottest in the East Tintic district which is generally agreed to be underlain at depth by a hot spring system. When the mine was reopened in 1947, after being closed down for ten years or so, Lovering seized upon the opportunity to determine the wall-rock temperatures before the workings were ventilated and cooled. We found that the temperatures increased rapidly with depth, and when Jim O'Dell [another of Tom's assistants] and I moved into the workings of the 1,100-foot level, we encountered oxygen-deficient, stagnant air and wall-rock temperatures of 137 degrees. Soon overcome by heat prostration and anoxia, it took

> awhile for us to drag ourselves back to the relatively good air and the cooler (100-degree) temperatures at the shaft station. Farther along in the same drift where we had been working, the original miners had reported temperatures of 155-165 degrees, but we were not foolhardy enough to try to confirm these numbers in the presence of such bad air.

Hal relates another unpleasant situation:

> Another incident that has stayed in my mind involves a chance encounter with a burly and unpredictable survivalist, definitely an unsavory individual. While following a very dim and rutted road in southwestern Utah, Chris Heropoulos, a Survey colleague, and I came upon this character banking dirt with a small bulldozer against a blockhouse-like structure built of railroad ties that was apparently under construction. He immediately demanded to know why we were trespassing on his property. I started to explain that we had not seen any no-trespassing signs along the road that we had been following, but before I could finish, he cut me off by saying that if he had his way, every government employee would be lined up against a wall and shot. I laughed a little nervously at this outburst, but he just looked at me with a steely eye and said that he was not joking. He went on to denounce all forms of government—local, state, and federal—and then launched into a long, gory description of the racial wars that he insisted would soon sweep over the nation. It would become the true Armageddon, with every man fending for himself. This tirade went on and on, and when it was over, I thought I detected a softening in his attitude toward us, so I asked if he would give us permission to look at the old mine and prospects we had come to examine. With this he again exploded in anger and said that all he would give us was five minutes to get off his land before he started shooting, and waved his arm toward two rifles in the gun rack of his truck. It goes without saying that we lost no time in leaving. We completed our map of that area by air-photo interpretation.

"He was hard-working, ethical, fun to be with in the field, competent, and observant. Utah geology has been much elucidated by his dedicated efforts."

Ed Tooker, a long-time friend and USGS colleague, writes:

> I guess some of my fondest memories occurred during many early field trips when Hal patiently helped acquaint me, an eastern interloper, with some of the significant geologic features of the Utah region. One attribute of Hal's that I personally resent, because he completely outclasses me, is his tremendous, almost photographic, instant recall of names, places, mine production data, and details of complex mining district geology (Rudy Kopf and Myron Best also attest to Hal's incredible memory). Hal's contributions [in collaboration with Tom Lovering] to the literature of wall-rock alteration and the stratigraphy and geologic structures at East Tintic are landmark documents. Hal received the Department of the Interior's Meritorious Service Award in 1976 for his achievements as a scientific administrator and research scientist in the field of mineral resources. He was an active participant on committees in the Society of Economic Geology, was a lecturer at university and professional society meetings, and was a delegate to an international resource conference. He was nominated by his colleagues in the Branch of Western Mineral Resources for the Distinguished Service Award.

Rudy Kopf, another USGS geologist, was Hal's field assistant in the West Tintic Mountains, the Sheeprock Mountains, and the Simpson Mountains from about 1964 to 1980 (when funds permitted). Rudy recalls that Hal had many admirable traits. Among them were "honesty, always a gentleman, and the ability of explaining complex geologic concepts in simple language, a talent few geologists have mastered." Hal was very dedicated to a task and Rudy says that "Hal would be halfway up a hill before I could get my backpack out of the vehicle." However, Rudy states that Hal also has a lighter side:

> Hal was one of several gifted writers of some early USGS Pick and Hammer shows which were annual in-house comedy skits largely devoted to puncturing the balloons of fellow Survey geologists whose egos had become over-inflated. In one skit, Hal played the role of a mafia gang member named Sam Mateo. He played the part to the hilt." (Hal, however, emphatically asserts that his most challenging role was as "Gertie, the ugliest bar girl in the Bottle Mountain Bar" in the Nevada show of 1958).

Hal and Lehi Hintze were underclassmen in the Geology Department at the University of Utah in the years of 1940 and 1941. Many years later, Hal and Lehi crossed paths once again. Lehi was teaching at Brigham Young University (BYU) and Hal was finishing some quadrangle maps around the San Francisco mining district west of Milford. The BYU field-camp students had mapped some of this area and Hal used the information in his map compilations. Lehi states that Hal "was always the complete professional government geologist." He "was hardworking, ethical, fun to be with in the field, competent, and observant. Utah geology has been much elucidated by his dedicated efforts."

Paul Proctor, another of Hal's classmates at the University of Utah, relates the following tales:

> While majoring in geology at the University of Utah, Hal served as Bronson Stringham's mineralogy lab assistant. Bronson emphasized hand specimen identification and some students became so good at recognizing the department's specimens that when Hal would toss one in the air, the students could often name it and give its chemical composition before it came down.
>
> While mapping rock alteration in the Tintic mining district with Lovering, Hal and Tom found that certain kinds of alteration showed up better on wet rocks than dry ones. Some observers reported that Hal and Tom literally licked their way across the entire district.

Hal's geologic mapping, descriptions and interpretations of structures, and shrewd comprehensions of ore deposits, all comprise an illuminated banner that lights the path for others to follow. The State of Utah owes a deep debt of gratitude to Hal T. Morris!

Selected Chronologic Bibliography of Hal T. Morris

Lovering, T. S., Sokoloff, V. P., and Morris, H. T., 1948, Heavy metals in altered rocks over blind ore bodies, East Tintic district, Utah: Economic Geology, v. 43, no. 5, p. 384-399.

Lovering, T. S., Stoll, W. M., Wadsworth, A. H., Wagner, H. V., Stringham, B. F., Morris, H. T., Hilpert, Lowell, Smith, J.F., Terrones, Alberto, Bonorino, F.G., Odell, J.W., and Mapes, Eduardo, 1949, Rock alteration as a guide to ore, East Tintic district, Utah: Economic Geology Monograph 1, 64 p.

Almond, Hy, and Morris, H. T., 1951, Geochemical techniques as applied in recent investigations in the Tintic district, Utah: Economic Geology, v. 46, no. 6, p. 608-625.

Morris, H. T., and Lovering, T. S., 1952, Supergene and hydrothermal dispersion of heavy metals in wallrocks near ore bodies, Tintic district, Utah: Economic Geology, v. 47, no. 7, p. 685-716.

Disbrow, A. E., and Morris, H. T., 1957, Ore deposits of the North Tintic mining district, *in* Cook, D.R., editor, Geology of the East TinticMountains and ore deposits of the Tintic mining districts: Utah Geological Society, Guidebook to the geology of Utah no. 12, Salt Lake City, p. 140-154.

Morris, H. T., 1957, General geology of the East Tintic Mtns., Utah, *in* Cook, D.R., editor, Geology of the East Tintic Mountains and ore deposits of the Tintic mining districts: Utah Geological Society, Guidebook to the geology of Utah, no. 12, Salt Lake City, p. 1-56.

Lovering, T. S., and Morris, H. T., 1959, Geological and geochemical factors in the discovery of blind ore bodies in the East Tintic district, Utah: Mining Engineering, v. 11, no. 12, p. 1232.

Bush, J. B., Cook, D. R., Lovering, T. S., and Morris, H. T., 1960, the Chief Oxide-Burgin area discoveries, East Tintic district, Utah: Economic Geology, v. 55, no. 6, p. 1116-1147, and v. 55, no. 7, p. 1507-1540.

Lovering, T. S., Morris, H. T., Stoll, W.M., Wagner, H.V., Wadsworth, A.H., Stringham, B.F., Hilpert, Lowell, Terrones, Alberto, Smith, J.F., Odell, J.W., and Disbrow, Allen, 1960, Geologic and alteration maps of the East Tintic district, Utah: U.S. Geological Survey Mineral Investigations Map MF-230, scale 1:9,600.

Morris, H. T., and Lovering, T. S., 1961, Stratigraphy of the East Tintic Mountains, Utah, with a section on Quaternary deposits by H. D. Goode: U.S. Geological Survey Professional Paper 361, 140 p.

Mabey, D. R., Crittenden, M. D., Jr., Morris, H. T., Roberts, R. J., and Tooker, E. W., 1964, Aeromagnetic and generalized geologic map of part of north-central Utah: U.S. Geological Survey Geophysical Investigations Map GP-422, scale 1:250,000.

Morris, H. T., 1964a, Geology of the Eureka quadrangle, Utah and Juab Counties, Utah: U.S. Geological Survey Bulletin 1142-K, p. K1-K26, scale 1:24,000.

Morris, H. T., 1964b, Geology of the Tintic Junction quadrangle, Tooele, Juab, and Utah Counties, Utah: U.S. Geological Survey Bulletin 1142-L, p. L1-L23, scale 1:24,000.

Morris, H. T., 1964c, Limestone and dolomite, *in* Mineral and water resources of Utah: Utah Geological and Mineralogical Survey Bulletin 73, p. 188-194.

Lovering, T. S., and Morris, H. T., 1965, Underground temperatures and heat flow in the East Tintic district, Utah: U.S. Geological Survey Professional Paper 504-F, p. F1-F28.

Roberts, R. J., Crittenden, M. D., Jr., Tooker, E. W., Morris, H. T., Hose, R. K., and Cheney, T. M., 1965, Pennsylvanian and Permian basins in northwestern Utah, northeastern Nevada, and south-central Idaho: American Association of Petroleum Geologists Bulletin, v. 49, no. 11, p. 1926-1956.

Morris, H. T., and Kopf, R. W., 1967, Breccia pipes in the West Tintic and Sheeprock Mountains, Utah: U.S. Geological Survey Professional Paper 575-C, p. C66-C71.

Morris, H. T., and Kopf, R. W., 1970a, Preliminary geologic map and cross section of the Cherry Creek quadrangle and adjacent part of the Dutch Peak quadrangle, Juab County, Utah: U.S. Geological Survey Open-File release, February 3, 1970.

Morris, H. T., and Kopf, R. W., 1970b, Preliminary geologic map and cross section of the Maple Peak quadrangle and adjacent part of the Sabie Mountain quadrangle, Juab County, Utah: U.S. Geological Survey Open-File release, February 3, 1970.

Morris, H. T., 1975, Geologic map and cross sections of the Tintic Mountain quadrangle and adjacent part of the McIntyre quadrangle, Juab andUtah Counties, Utah: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-883, scale 1:24,000.

Morris, H. T., 1977, Geologic map and sections of the Furner Ridge quadrangle, Juab County, Utah: U.S. Geological Survey Miscellaneous Investigations Map I-1045, scale 1:24,000.

Morris, H. T., Douglass, R. C., Kopf, R. W., 1977, Stratigraphy and microfaunas of the Oquirrh Group in the southern East Tintic Mountains, Utah: U.S. Geological Survey Professional Paper 1025, 22 p.

Batchelder, J. N., O'Neil, J. R., Morris, H. T. and Mogensen, A. P., 1978, Geochemistry of fluid inclusions in selected ores from the East Tintic district, Utah: International Association on the Genesis of Ore Deposits, 5th Symposium, Snowbird near Salt Lake City, Utah, U.S.A., August, 1978.

Morris, H. T., 1978, Preliminary geologic map of Delta 2° quadrangle, west-central Utah: U.S. Geological Survey Open-File Report 78-705, scale 1:250,000.

Morris, H. T., and Mogensen, A. P., 1978, Tintic mining district, Juab and Utah Counties, Utah, *in* Shawe, D.R. editor, Guidebook to mineral deposits of southwestern Utah: Utah Geological Association Publication 7, p. 41-47.

Lemmon, D. M., and Morris, H. T., 1979, Preliminary geologic map of the Frisco quadrangle, Beaver County, Utah: U.S. Geological Survey Open-File Report 79-724, 18 p., scale 1:48,000.

Morris, H. T., and Lovering, T. S., 1979, General geology and mines of the East Tintic mining district, Utah: U.S. Geological Survey Professional Paper 1024, 203 p., scale 1:9,600.

Morris, H. T., Best, M. G., Kopf, R. W., and Keith, J. D., 1982, Preliminary geologic map and cross sections of the Tetons quadrangle and adjacent part of the Observation Knoll quadrangle, Beaver and Iron Counties, Utah: U.S. Geological Survey Open-File Map 82-778, scale 1:24,000.

Abbott, J. T., Best, M. G., and Morris, H. T., 1983, Geologic map of the Pine Grove - Blawn Mountain area, Beaver County, Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I-1479, scale 1:24,000.

Morris, H. T., 1983, Interrelations of thrust and transcurrent faults in the central Sevier orogenic belt near Leamington, Utah, *in* Miller, D. M., Todd, V. R., and Howard, K. A., editors, Tectonic and stratigraphic studies in the eastern Great Basin: Geological Society of America Memoir 157, p. 75-81.

Steven, T. A., and Morris, H. T., 1983, Geologic map of the Cove Fort quadrangle, west-central Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I-1481, scale 1:50,000.

Hintze, L. F., Lemmon, D. F., and Morris, H. T., 1984, Geologic map of the Frisco Peak quadrangle, Millard and Beaver Counties, Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I-1573, scale 1:48,000.

Lemmon, D. M., and Morris, H. T., 1984, Geologic map of the Beaver Lake Mountains quadrangle, Millard and Beaver Counties, Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I-1572, scale 1:48,000.

Steven, T. A., and Morris, H. T., 1984, Mineral Resource potential of the Richfield 1° x 2° quadrangle, west-central Utah: U.S. Geological Survey Open-File Report 84-521, 53 p. scale 1:250,000.

Morris, H. T., 1985 Geology, ore bodies, and halloysite deposits of the Tintic mining district, Utah *in* Hall, R.B. editor, Guidebook, Excursion 06, International Clay Conference, Denver, Colorado, July 28 - August 2, 1985, p. 40-53.

Best, M. G., Morris, H. T., Kopf, R. W., and Keith, J. D., 1987, Geologic map of the southern Pine Valley area, Beaver and Iron Counties, Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I-1794, scale 1:50,000.

Morris, H. T., 1987a, Preliminary geologic map of the Delta 2° quadrangle, Tooele, Juab, Millard, and Utah Counties, Utah: U.S. Geological Survey Open-File Report 87-185, scale 1:250,000.

Morris, H. T., 1987b, Preliminary geologic structure map of the Delta 2° quadrangle and adjacent areas, west-central Utah: U.S. Geological Survey Open-File Report 87-189, scale 1:500,000.

Best, M.G., Lemmon, D. M., and Morris, H. T., 1990, Geologic map of the Milford quadrangle and east-half of the Frisco quadrangle, Beaver County, Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I-1904, scale 1:50,000.

Steven, T. A., Morris, H. T., and Rowley, P. D., 1990, Geologic map of the Richfield 1° x 2° quadrangle, west-central Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I-1901, scale 1:250,000.

TUFA DEPOSITS in western Grand County

by Hellmut Doelling

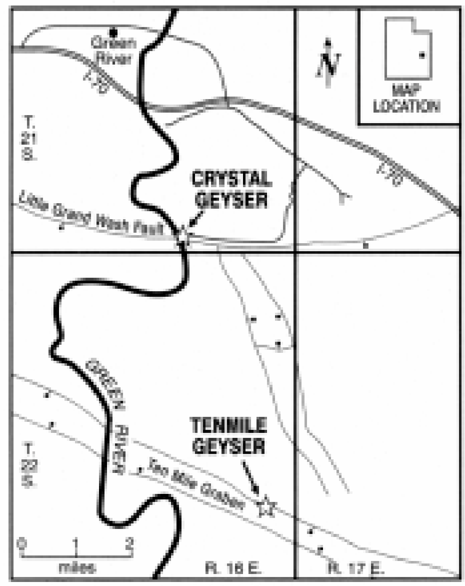
Mineral-charged waters of cold-water, carbon dioxide-driven geysers and springs deposit travertine and tufa. Travertine is a mineral consisting of massive, usually layered calcium carbonate (as aragonite or calcite), usually formed as a spring deposit. Tufa is a porous rock formed as a spring deposit, not necessarily of calcium carbonate. Both layered and porous varieties are present in western Grand County and both consist of calcium carbonate so I will refer to both as tufa deposits. They are found as high as 165 feet above current erosional levels, indicating that deposition has been active in the area for at least the past 200,000 years. Some tufa deposits are active; they continue to accumulate calcium carbonate from the mineral matter brought to the surface by the spring water. Others are inactive; they are not receiving new deposits and are undergoing erosion.

The tufa deposits are found in two distinct areas, respectively located about 4.5 miles and 10 miles south of Green River, Utah. The tufa area closest to the Green River is associated with Crystal Geyser in the SE¼, SE¼, section 34, T. 21 S., R. 16 E. (SLBM), and the second area is associated with Tenmile geyser (informal name) located along Salt Wash, SW¼, SE¼, section 25, T. 22 S., R. 16 E.

Water from Crystal Geyser contains 11,000 to 14,000 parts per million (ppm) total dissolved solids and is rich in sodium, calcium bicarbonate, chloride, and sulfate (Barton and Fuhriman, 1973 as reported in Baer and Rigby, 1978). Good drinking water usually contains less than 300 ppm. The Tenmile geyser was not checked but should be similar.

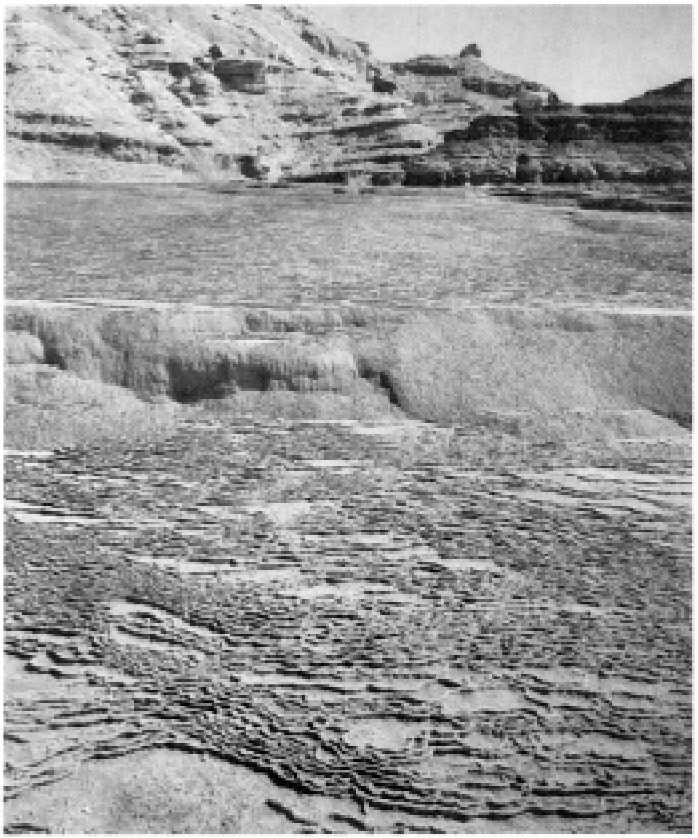
Active Tufa Deposits

The mineral-charged waters of geysers and springs form tufa and travertine deposits. Welsh and others (1980, p. 82) indicated that certain species of algae may be involved in the precipitation of the calcium carbonate. Bright-yellow ochre to dusky-reddish-brown coloration (iron oxides) adorns deposits actively adding calcium carbonate. The tufa surface displays thousands of small terraces, each with an undulating floor and marginal lip. The active deposit at Crystal Geyser extends 215 feet east from the Green River and is 240 feet wide north to south. The standpipe of an old petroleum test well, the Ruby No. 1-X from which most of the water now erupts, is only 25 feet west of the eastern edge of the deposit. Inactive tufa extends another 40 feet to the base of the Summerville Formation bluffs. Several spring pools, each surrounded by a few feet of active tufa, are found within this otherwise inactive 40-foot tufa zone.



The active zone of tufa around Tenmile geyser, which also erupts from a standpipe, is relatively small. The yellow ochre to dusky-reddish-brown coloration is very noticeable, but extends only 10 to 15 feet. The geyser is located in the alluvial plain of Salt Wash, a tributary of the Green River which flows in the Tenmile graben. The dimensions of this tufa deposit indicate that the water does not erupt very high. Active algal action is limited to areas of wetting.

Not far from Tenmile geyser is a natural mineral-charged spring that forms a pool 2 by 3 feet in diameter and 6 inches deep. At the bottom of the pool are three holes that discharge effervescing gas-charged cold water. At the time of my visit, the pool overflowed at the rate of only two quarts each minute. Nevertheless, the pool



Tufa terraces form around Crystal Geyser. Active tufa deposits exhibit bright yellow ochre to dusky red coloration.

Crystal Geyser. The effervescing waters rise 70 to 100 feet during eruptions which occur irregularly with irregular duration. The CO_2-charged waters are laden with dissolved chemical matter that give rise to tufa and travertine deposits.

is surrounded by a shield of tufa, 80 x 140 feet in diameter, which rises about 2.5 feet above the surrounding ground surface.

Inactive Tufa Deposits

An older tufa deposit is present south of the active deposit at Crystal Geyser. The drab light-yellowish gray deposit is very porous, crudely laminated, and weathers into plates and platelets up to an inch thick. The small terraces, so well developed in the active deposits, are no longer present and were probably destroyed by erosion long ago.

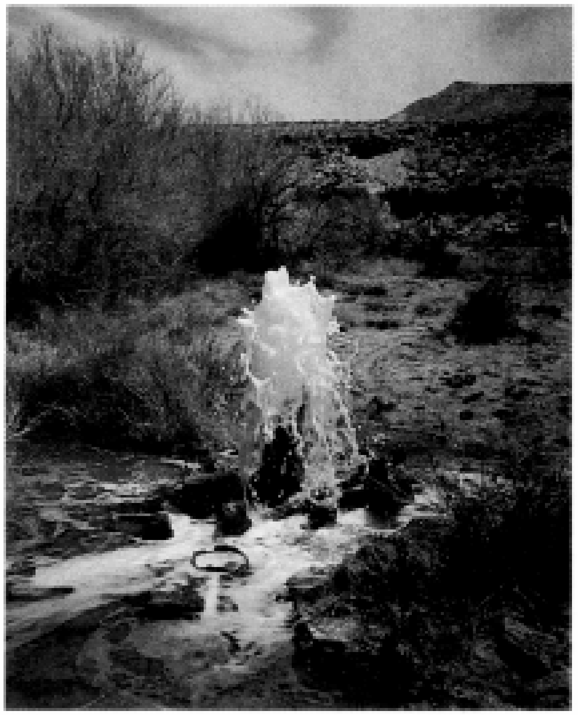
Splintery spar (calcium carbonate crystals) weathers from the travertine layers. Beds of white or slightly yellowish calcite or aragonite, as much as two feet thick with mammillary surfaces, are exposed. The deposit is about 475 feet long (north-south) and 225 feet wide (east-west). The maximum observable thickness is about 15 feet near its northern end; it thins to the south. This is the level 2 tufa of Baer and Rigby (1978, p. 127). Their level 1 deposits are the oldest; their level 3 is the active Crystal Geyser deposit.

The level 2 deposit is several feet higher than the active level. Baer and Rigby noted that the two were not significantly different in age. This shows that cold water, carbon dioxide-driven geysers were active in the past. No human intervention, such as the drilling of wells, is necessary for spring and geyser activity.

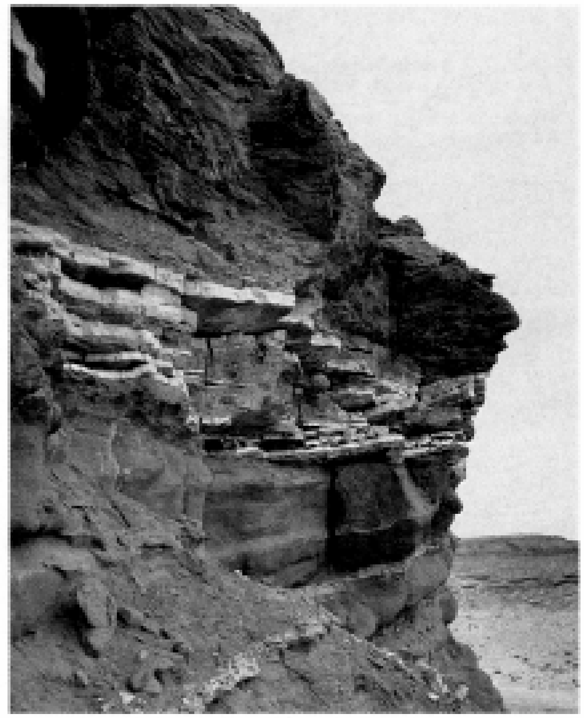
Fossil tufa deposits are irregularly found along the Little Grand Wash fault, which provided the conduit for the rising water. These deposits are scattered for 1.25 miles east of the Green River and are the level 1 deposits of Baer and Rigby (1978). The largest deposit observed is 600 feet long and as much as 25 feet thick. Erosion has isolated most of these deposits on the tops of bluffs and ridges. The height above present drainage levels is as much as 150 feet. Woodward-Clyde Consultants (1980, p. 40) indicated that 95 percent of the erosion rates on the Colorado Plateau were less than or equal to 0.8 feet per thousand years in Quaternary time. If this is the case then the geysers and springs along the Little Grand Wash fault have been active for about 190,000 years.

At least five levels of tufa are present in the Tenmile geyser area along the fault on the northeast side of the Tenmile graben. The level immediately above the active deposits is the largest areally and is found about 15 feet above the level of the geyser. The active spring pool tufa shield rises above this level. The next higher level is extensive but has undergone considerable erosion. It lies about 40 feet above the geyser. The fourth level of tufa deposition covers the tops of many buttes 110 feet above the geyser. Only a few remnants of a fifth level are found on the tops of still higher buttes, 165 feet above the geyser. At the 0.8 ft/1000 year rate, the highest deposits were laid down more than 200,000 years ago.

Some deposits lie directly over faults and travertine laminae are bent sharply over them. It cannot be conclusively shown, however, that fault movement displaced and shattered



Tenmile geyser during eruption. Effervescing waters rise 3 to 7 feet during widely spaced and irregular events of irregular duration. Sand blows over tufa between eruptive events.



Travertine interbedded and overlain by consolidated eolian sand on bluff near Tenmile geyser.

tufa. The travertine may have formed in inclined fashion because the mineral-charged waters cascaded over existing relief. Some of the tufa laminae have dips exceeding 60 degrees. Vertical tufa laminae are also observable, usually filling open fractures that cut more horizontally inclined deposits.

Calcite and aragonite (travertine) layers are commonly interbedded with sandstone. These sandstone beds grade laterally into porous tufa and are composed of sand blown across spring and geyser areas during inactive periods. This sandstone is more contorted than the Jurassic Entrada Sandstone over which the tufa has accumulated.

A few conduits through which water migrated to higher levels have been exposed by erosion. The normal reddish or orange rock of the Entrada Sandstone is bleached to pale-yellow in the conduits. The conduits appear as vertical columns of irregular bleaching in the sandstone. The margins of many fractures and joints in the host rock have been bleached as well. Some poorly cemented Entrada horizons have been completely bleached to the pale-yellow color and are now exposed over an area of at least 0.5 mile by 1,000 feet.

At several places the fossil tufa deposits have been exploited to produce decorative or ornamental stone. Banding and patterning in the colorful rock is interesting and beautiful. In most places, however, the deposits are too brittle to produce large pieces.

Geysers

The geology of Crystal Geyser has been reported by McKnight (1940), Baer and Rigby (1978), and by Barton and Fuhriman (1973). The origin of the carbon dioxide exsolving groundwater systems have been discussed by Mayo and others (1991). They believed the carbon dioxide is attributable to high-temperature thermal decomposition of carbonate minerals at depth and that the gas has migrated long distances before reaching the point of eruption. They also suggested the water is of meteoric origin and erupts from ground-water systems with limited circulation depths. Baer and Rigby (1978, p. 128) indicated the source of the high chemical concentrations is unknown. The area is underlain by the salt-bearing Pennsylvanian-aged Paradox Formation which suggests leakage or contamination through the fault zone conduits.

Baer and Rigby (1978) reported that Crystal Geyser erupted from 6 to 8 minutes each 4 hours and 15 minutes in June of 1968 and July of 1972. Local people in Green River indicated that the geyser erupted every 12 to 18 hours between 1987 and 1991. On February 9, 1987 Crystal Geyser erupted at 5:10 p.m. Before the eruption started, water flowed from the standpipe for ½ hour. At 5:10 p.m. the water suddenly rose 70 to 80 feet for 10 to 15 seconds, then receded, sputtered, and shot up again to full height. This process was repeated until 5:28 p.m. After that, water flowed and sputtered from the standpipe for an additional 10 minutes. The nearby pools bubbled and boiled simultaneously.

About 3 p.m. on May 2, 1991, as I approached Crystal Geyser from the south, I could see it erupting from a distance of about three miles. I travelled another ten minutes before reaching the geyser which erupted for another 10 to 15 minutes. It is apparent that the duration of eruptions and time between eruptions varies with time and may vary with season.

There are no reports in the literature about the Tenmile geyser because of

Continued on page 13 . . .

Anatomy of a rock fall

by Grant C. Willis

Rock falls, landslides, earthquakes, and floods are all vivid reminders that geology is "alive". A noteworthy rock fall occurred in Dark Canyon in the Book Cliffs near the Utah-Colorado border during the spring or early summer of 1991. This rock fall is of particular interest because the process of the fall is imprinted on the rock and soil at the site. There were no injuries or damage, although rubble landed less than 300 feet from a nearby gas-field access road. Rock falls are not unusual for this area; most slopes are littered with rock-fall boulders.

The fall involved the upper part of the Late Cretaceous Tuscher Formation, a thick sequence of fluvial-lacustrine (river- and lake-deposited) strata. The Tuscher consists of massive, cliff-forming, fluvial channel sandstone beds interbedded with slope-forming mudstone. This combination of strata is particularly conducive to landslides and rock falls. Water seeps into joints and pores in the permeable sandstone and percolates down to the impermeable mudstone layer. Clay absorbs water and expands, reducing friction, causing the layer to lose strength. Gravity then allows the overlying sandstone block to move downslope over the "slippery" clay. Wedging from repeated freeze-thaw cycles, growth of mineral crystals, and roots can also pry blocks apart, eventually destabilizing fractured blocks.

Debris formed a large fan on the slope below the rock fall.

Commonly, rock falls and landslides develop where strata incline toward the slope, allowing sliding blocks to take advantage of the natural tilt of the bedding. At the Dark Canyon site however, the beds are inclined about five degrees north, but the rock fall moved south, opposite the natural incline. This hints at the significant role of weathering and wedging in moving and destabilizing large blocks of rock.

Primary factors causing the rock fall were: 1) the wet clay-bearing mudstone footing, 2) large, open joints, 3) wedging or prying by frost, plants, and possibly growth of travertine crystals, 4) weathering and erosion of slope-forming material at the foot of the block.

Sequence of events in the Dark Canyon rock fall:

The sandstone bed fractured into large blocks thousands of years ago. Water (which expands when it freezes), crystal growth, and plant roots gradually wedged the blocks apart. The fractures were held open by soil, rocks, and roots.

Weathering gradually altered the mudstone beneath the block, reducing the strength of the rock, and allowing water to create a slippery base.

About the Author

Grant Willis earned BS (1981) and MS (1984) degrees from Brigham Young University. He worked for the U.S. Forest Service in central Idaho and for the U.S. Geological Survey in the Brooks Range of northern Alaska while completing his degrees. He mapped in the Book Cliffs area of eastern Utah for his master's thesis.

Grant was hired by the Utah Geological Survey when the 7½ minute quadrangle mapping program was created in 1983 and has been in the mapping program since that time. He mapped in the Salina and Aurora area of central Utah, Antelope Island, in the eastern Book Cliffs near the Colorado border, and along Westwater Canyon, and is currently mapping the Richfield quadrangle.

Large joints were initially opened by freezing water, growth of travertine crystals, and plant roots. Rocks and soil filled the void, holding the blocks apart and providing more space for the process to continue.

The weight of the block compressed the weakened mudstone to form an incline with a slope of about 15 degrees toward the open slope.

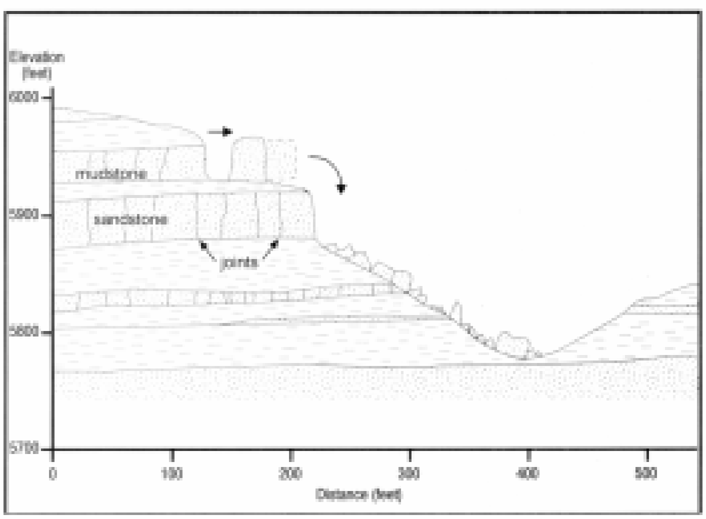
The block slid down the incline, plowing up a pile of debris.

The front half of the block overrode the debris and became suspended; eventually the block fractured into two parts (it did not break along a pre-existing joint); once fractured, the front half of the block toppled over the cliff, gouging a trench and shearing off the top lip of the cliff.

The block shattered on impact, sending huge boulders and dislodged debris cascading downslope in a broad fan. The largest boulders are up to 27 feet wide. Rubble up to 10 feet in diameter, and much smaller debris, form a broad rubble zone 110 feet wide and 200 feet long.

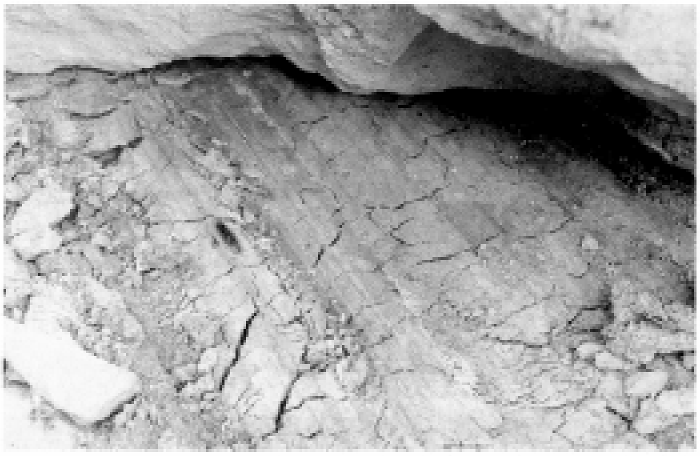
The other half of the block did not fall from the cliff, but slid forward a few feet more, gouging up more rubble before coming to a rest with a slight forward tilt. This half-block is 38 feet high, and 26 feet wide. It is now 22 feet farther downslope of its original position, and is 28 feet from the edge of the cliff.

The Dark Canyon rock fall is a textbook example and clearly shows the significance of most major contributing factors. The occurrence on a slope opposite the inclined strata is uncommon, but shows the importance of weathering of the mudstone layer beneath the thick sandstone cliff.



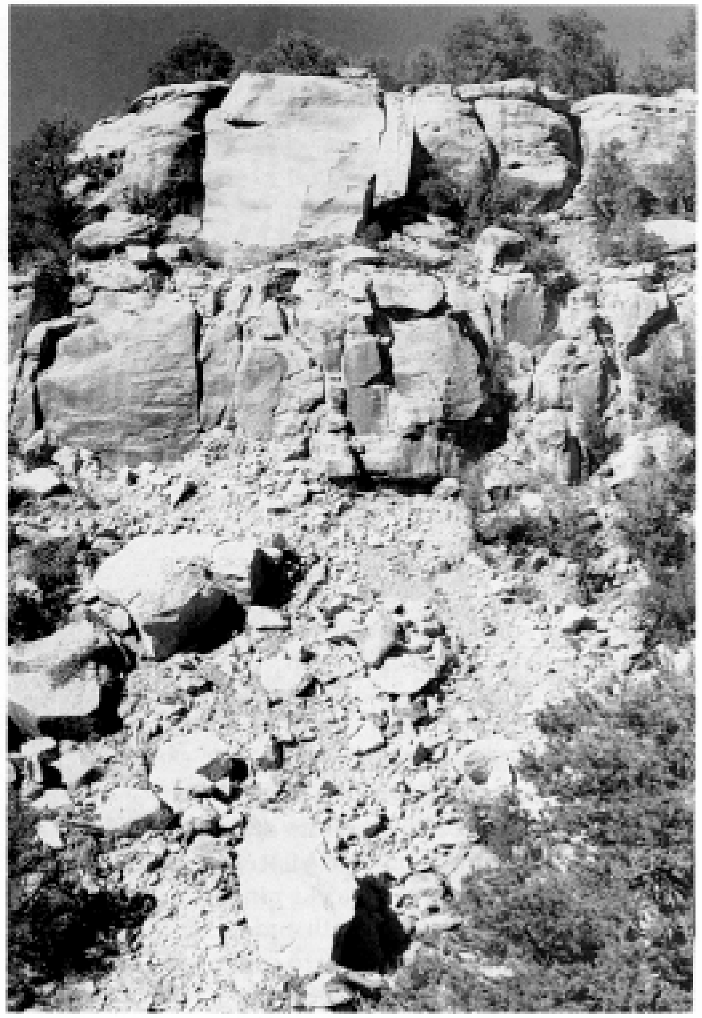
Sketch showing the relationship of the rock fall to the geology and topography.

Thick travertine is common in open joints, and probably contributed to wedging of the blocks.



Grooves called "striations" formed in wet mud as the large block slid downslope (away from viewer).

Large pile of rubble gouged by the front edge of the sliding block. The front half of the block overrode the debris and then fractured, falling over the ledge just to the left of the photograph.



View toward the fallen block and rubble zone. The white block in the upper middle is the back half of the slide block. The upper block is about 40 feet tall. The large block in the left center is 15 by 22 feet.

. . . continued from page 10

its unimpressive eruptions. On May 3, 1991 it erupted for about 15 minutes. It sputtered and spurted to a maximum height of 6 or 7 feet; mostly the water rose only 3 or 4 feet. I left before recording the full duration of the eruption. I visited the geyser later in the summer and the area around the standpipe was completely dry.

Cited References and Other Literature

Baer, J.L. and Rigby, J.K., 1978, Geology of the Crystal Geyser and environmental implications of its effluent, Grand County, Utah: Utah Geological and Mineral Survey Utah Geology, v. 5, no. 2, p. 125-130.

Barton, J.R. and Fuhriman, D.K., 1973, Crystal Geyser Project—A study of some alternative methods for eliminating the salt contribution of Crystal Geyser from the Green River: Provo, Utah, Center for Environmental Studies, Brigham Young University, 55 p.

Mayo, A.L., Shrum, D.B., and Chidsey, T.C., Jr., 1991, Factors contributing to exsolving carbon dioxide in ground-water systems in the Colorado Plateau, Utah, in Chidsey, T.C., Jr., editor, Geology of east-central Utah: Utah Geological Association Publication 19, p. 335-342.

McKnight, E.T., 1940, Geology of area between Green and Colorado Rivers, Grand and San Juan Counties, Utah: U.S. Geological Survey Bulletin 908, 147 p.

Welsh, S.L., Rigby, J.K., and Hamblin, W.K., 1980, Crystal Geyser in A survey of natural landmark areas of the north portion of the Colorado Plateau—biotic and geologic themes: Provo, Utah, Brigham Young University, prepared for the Heritage Conservation and Recreation Service, U.S. Department of the Interior, p. 82-84.

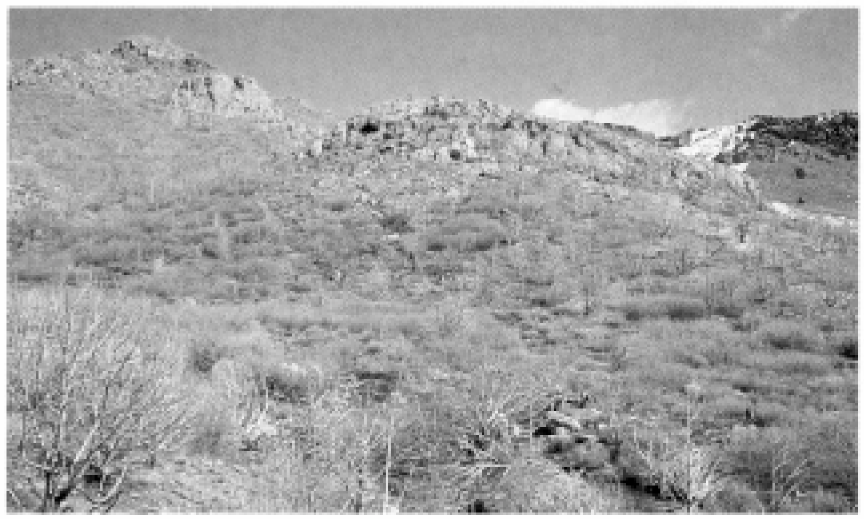
Woodward-Clyde Consultants, 1980, Overview of the regional geology of the Paradox basin study region: U.S. Department of Energy, ONWI 92-draft 165 p.

Large mass-movement on the west side of the Canyon Mountains, Millard County

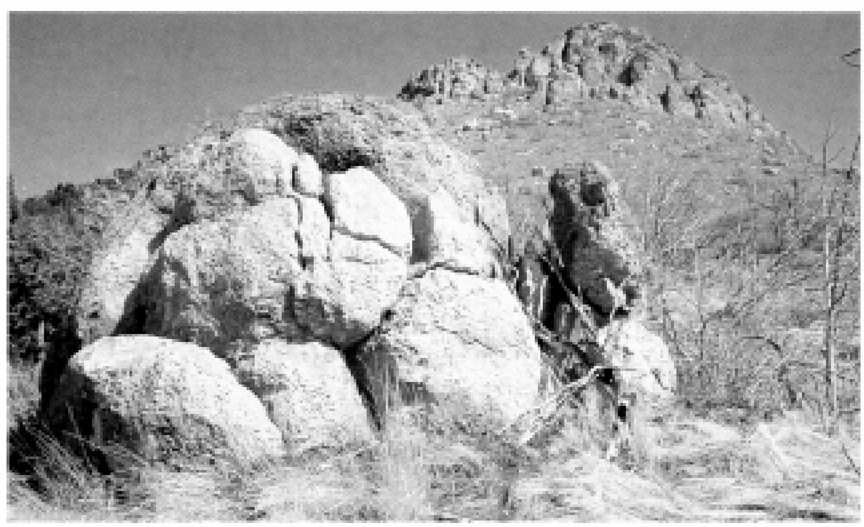
by Fitz Davis

In an area south and southeast of Oak City, large blocks of Cambrian quartzite, limestone, and dolomite have rafted down the west side of the Canyon Mountains and now rest on and among the unconsolidated colluvium, debris flows, and coarse alluvium of the thick Oak City Formation (late Miocene and Pliocene). The largest blocks range from 200 to 12,800 feet in length and have exposed thicknesses of 10 to over 200 feet. The local relief is 3,200 feet, and in this dissected topography many of the large blocks are atop knolls or long, linear ridges. These and other large boulders are an integral part of the Oak City Formation. The blocks probably separated from Cambrian formations higher on the mountainside. Curiously, many if not all of these large blocks have been brecciated and re-cemented. Extreme examples are the intensely brecciated and re-cemented linear blocks of white Tintic Quartzite (Early and early Middle Cambrian) that form the long, north-south "Rocky Ridge".

In most of the rare exposures, the Oak City Formation consists of a jumbled mixture of mostly angular limestone and quartzite boulders, cobbles, and pebbles that are loosely cemented by a red, calcareous, silty and sandy matrix. Up close, the relationships of the large blocks to the surrounding and underlying deposits are obscured by thick piles of talus. However, the main giveaway



A view east in Clay Spring Wash showing a large brecciated carbonate block that has rafted down from the high ridge in the right background.



A view to the northeast in Clay Spring Wash showing a large brecciated carbonate block capping the knoll in the background and a broken carbonate boulder, 18 feet high, in the foreground.

to the origin of the blocks is a large carbonate block that clearly underlies the red deposits of the Oak City Formation. The relationship between the block and underlying formation reveals that the large blocks have been creeping or sliding downslope probably since the late Miocene or Pliocene time. However, a mystery remains! How did these huge blocks get brecciated and then re-cemented?

An intensely brecciated, re-cemented, and displaced block of white Tintic Quartzite atop "Rocky Ridge".

An exposure of the Oak City Formation in a roadcut. Boulders and cobbles of purple and white quartzite, gray limestone, reddish-gray conglomerate, and a yellowish-green sandstone are common in a red, calcareous, silty and sandy matrix. Hammer for scale.

Energy News

The Utah Oil Sample Bank and characteristics of Utah crude oils

by Thomas C. Chidsey, Jr., Robert W. Gloyn, Craig D. Morgan, and Carolyn M. Olsen

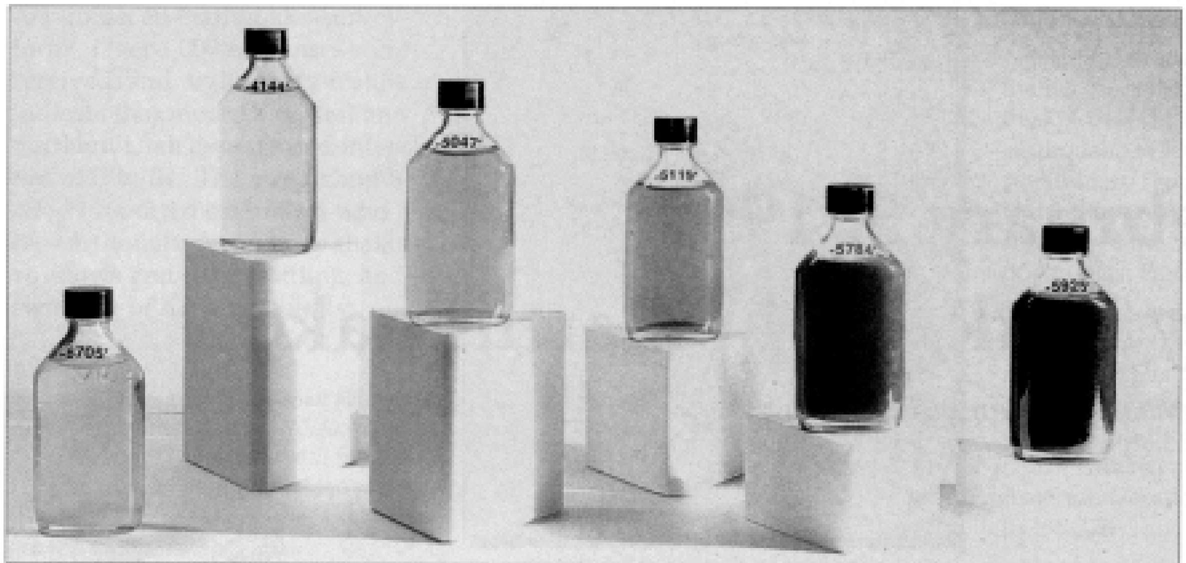
Production of oil in Utah is widely distributed throughout the state in over 150 fields in 11 counties. Productive reservoirs (porous rock units containing oil and gas) range in age from Devonian (400 million years ago) in the Paradox basin to late Tertiary (Pliocene - 5.3 million years ago) on the northeast side of the Great Salt Lake. In some areas, many oil fields produce from the same reservoir. For example, over 90 fields in the Uinta Basin produce oil from the Paleocene and Eocene (66.4 to 57.8 million years ago) Wasatch and Green River Formations and over 60 fields in the Paradox basin produce from the Pennsylvanian (320 million years ago) Paradox Formation. Other reservoirs produce from only a single field, such as the Pennsylvanian Weber Sandstone at the Ashley Valley field in the eastern Uinta Basin. Oil from different reservoirs and sometimes from different parts of the same reservoir (even within the same field) show different physical and chemical characteristics. These characteristics provide valuable information on the source, migration, and origin of the oil, and can be used to help explore for new oil accumulations.

In 1991, the Utah Geological Survey (UGS) initiated an oil-sampling program as part of a state-wide hydrocarbon source-rock study in cooperation with the U.S. Geological Survey. Oils collected for this program are available to industry and other researchers who are interested in determining the chemical composition and organic makeup of the oil. To determine the organic makeup, researchers identify individual molecular groups within the oil and the type of organisms from which these molecular groups originated. These groups are known as biomarkers. The biomarkers from the oil can be matched with biomarkers from organic-rich shales and other possible source rocks to determine which rocks generated the oil, and the thermal history and migration pathways of the hydrocarbons. This information is critical to finding new oil fields. Evaluation of the oils that come from small, isolated reservoirs is particularly important in order to pinpoint potential additional undiscovered accumulations.

The Utah Oil Sample Bank currently contains 81 representative samples from 29 reservoirs covering 40 oil fields. The samples are from all major fields in the state and from a number of smaller, scattered or isolated fields. Samples were donated by 34 field operators and were collected in cooperation with the Utah Division of Oil, Gas and Mining. The oil samples are stored at and can be borrowed from the UGS Sample Library. A complete listing of the samples, including well name and location, oil field, reservoir, and more is available from the UGS.

The UGS and Humble Geochemical Services are determining the basic physical characteristics of the oils as well as sulfur and nitrogen content. These analysis help determine the types of products, refinery processes, and price for individual crude oils. Physical characteristics include specific and API (American Petroleum Institute) gravity, pour point, viscosity, and color. API gravity is the measurement used the most by petroleum engineers and geologists to describe the density of oil. Generally, the higher the API gravity the better the oil is for refining. API gravities of Utah oils range from 5.6° to 69°. Tertiary oils from the Uinta Basin average 29.4° and Pennsylvanian oils from the Paradox basin average 40.2°.

Pour point is the lowest temperature at which an oil will flow. Pour points of Utah oils range from 5 to 130°F. Uinta Basin oils have high pour points, averaging 90°F, because of high paraffin (wax) content. Viscosity measurements are commonly expressed in the time required for a specific volume of liquid to flow through an orifice of a specific size at



Oils from Anschutz Ranch East field, Summit County, Utah. Sample bottles are labeled with subsea structural elevation. Photo by Christine Wilkerson.

a set temperature, usually 100°F. Pancake syrup has a viscosity of about 50 seconds; water has a viscosity of 25 seconds. The viscosity of Utah oils ranges from 34 seconds to 400 seconds.

The colors of Utah oils include various shades of brown, green, black, red, and yellow. Usually the color is indicative of the gravity and maturity of the oil (maturity is reflected by the types of hydrocarbons generated under certain temperature conditions and time durations). Color may be related to the percentage of the aromatic series of hydrocarbons (benzene, toluene, and more). In some cases, color can change with location or structural position, even within a single field. In Anschutz Ranch East field, for example, the color of the condensate oil changes with the structural position of the producing wells. The field contains two anticlines separated by a small thrust fault. Condensate on the crest of both anticlines is pale yellow and becomes darker (yellow through brown) with increasing depth. The color change is likely the result of gravity segregation within the reservoir; less dense (higher API gravity), lighter-colored hydrocarbons generally accumulate at the top of the anticlines.

Chemical characteristics of oil, and biomarkers are currently being determined. To date, thirty oils have been analyzed to help determine the source, migration, thermal history, and maturity of these oils. Although additional information is still being collected, some preliminary conclusions can be drawn from the chemical and biomarker analysis thus far performed on the oils. In the southern Paradox basin, the oil in both the Permian (280 million years ago) Coconino Sandstone and the algal mound and carbonate sand reservoirs of the Paradox Formation was generated from the same source. Prior to this study, the source of the oil in the Permian reservoir was unknown. In the northern Paradox basin, biomarker analysis shows that most oil in the Devonian to Pennsylvanian reservoirs originated from similar marine source rocks. However, these oils show different maturity characteristics, which indicate that the source rocks and the oils have had different thermal histories.

Many of the chemical and biomarker investigations were done by private industry and this information was generously donated to the UGS. Two major companies have already donated over $45,000 worth of oil analysis. This information will be released as a series of UGS open-file reports in the near future.

The UGS Sample Library loans, free of charge, oils and other geological samples to natural-resource companies, researchers, and other parties involved in exploring and developing Utah mineral and energy resources. The UGS requests copies of analysis or reports on the samples. This information can be kept confidential for a reasonable period of time.

For information contact:
Carolyn M. Olsen, Sample Librarian
UGS Sample Library
4060 South 500 West #4
Salt Lake City, UT 84123
(801)266-3512 Fax (801)467-4070

The February 3, 1994 Draney Peak, Idaho Earthquake

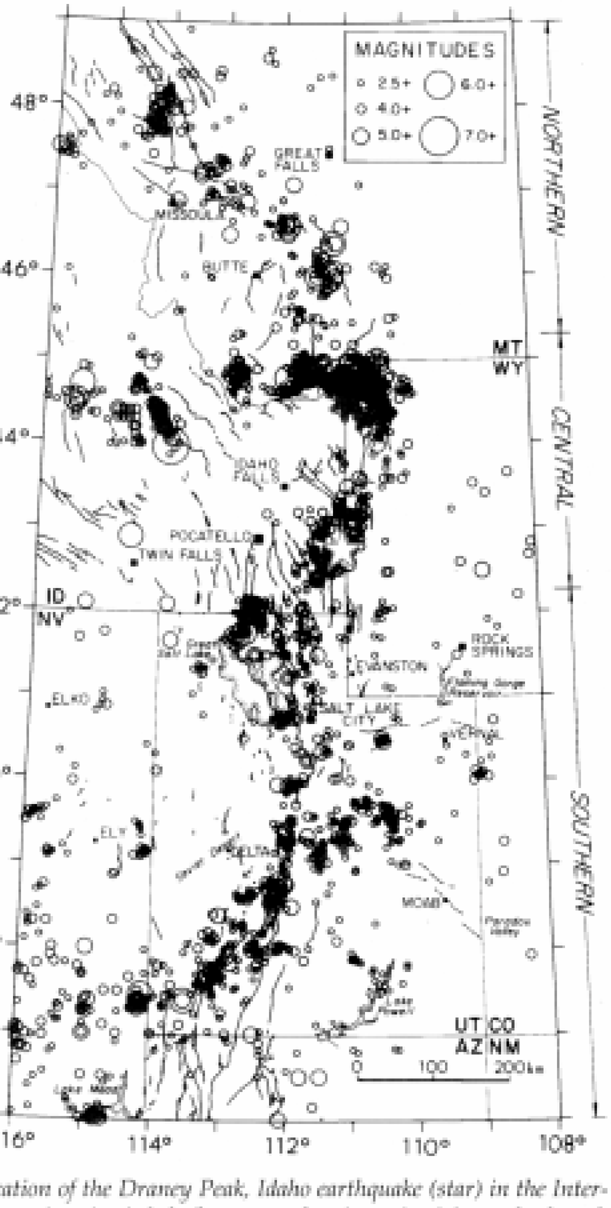
by Gary Christenson and Kimm Harty

At 2:05 a.m. MST on February 3, 1994, a magnitude 5.9 earthquake occurred in the Intermountain seismic belt along the Wyoming/Idaho border. The epicenter was in Idaho, but the nearest communities are Aurora and Afton, Wyoming, about 60 miles north of the Utah border. The area is sparsely populated and little damage was reported, although the earthquake was felt as far south as Moab, Utah, and Grand Junction, Colorado.

The epicenter was in a remote mountainous region. Poor access, winter weather conditions, and snow cover hampered post-earthquake field investigations. Detailed ground surveys have not been performed, and few geologic effects have been reported. Rock falls, snow cracks, and changes in spring flow were noted, but no evidence for liquefaction, surface fault rupture, or significant landslides has yet been found.

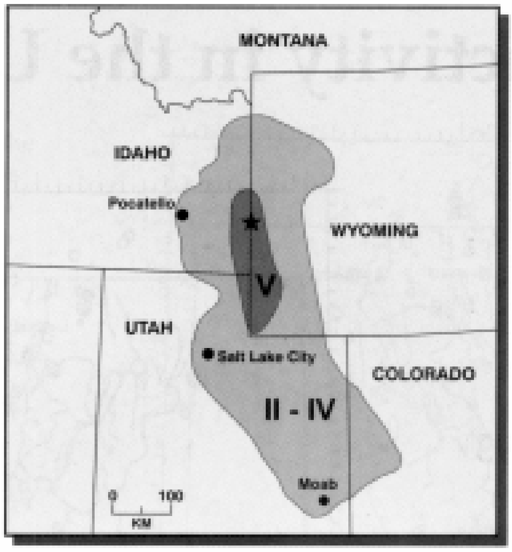
The earthquake was preceded by foreshocks up to magnitude 4.7, and has been followed by thousands of aftershocks, including three of magnitude 5 or greater (Nava and others, 1994). The preliminary focal mechanism of the main shock indicates normal faulting, but more analysis of the seismological data is necessary to better define the rupture plane and identify the fault. Aftershocks were predominantly south of the main shock, suggesting that the fault rupture propagated southward (Nava and others, 1994).

Ground shaking from the earthquake was widely felt, notably to the south along the Wasatch Front in Utah. The preliminary isoseismal map indicates that ground shaking was felt over a large area, particularly south of the epicenter, perhaps reflecting effects of the south-directed fault rupture. The maximum Modified Mercalli intensity (MMI) was VII near the epicenter, although the areas of MMI VI and VII are limited and too small to show.



Location of the Draney Peak, Idaho earthquake (star) in the Intermountain seismic belt (base map showing seismicity and selected Quaternary faults from Smith and Arabasz, 1991).

The Utah Geological Survey (UGS) also solicited MMI data by asking newspapers in central and northern Utah to publish an earthquake-survey form. Over 1,000 responses were received, and preliminary results indicate that much of central and northern Utah experienced intensities of II to III. The most common effects reported by Utahns who felt the earthquake were: beds shaking, windows and doors rattling, and swinging of hanging objects.



Preliminary isoseismal map of the Draney Peak, Idaho earthquake showing Modified Mercalli intensities (Roman numerals). Map courtesy of U.S. Geological Survey.

REFERENCES

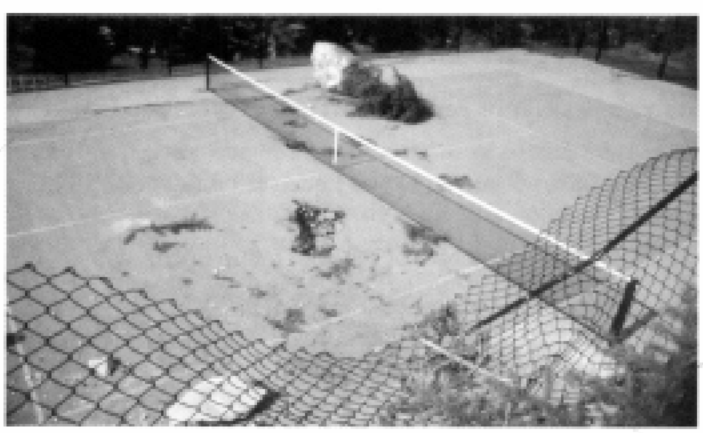
Nava, S.J., Arabasz, W.J., and Pechmann, J.C., 1994, The M 5.9 Draney Peak, Idaho (Idaho-Woming border) earthquake of February 3, 1994 — a preliminary report: Program for Northridge Abstracts, 89th Annual Meeting of the Seismological Society of America, Pasadena, California.

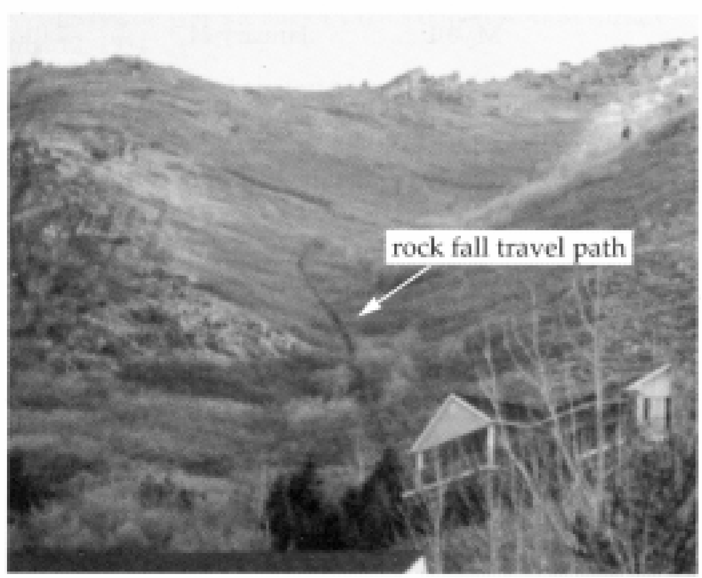
Smith, R.B., and Arabasz, W.J., 1991, Seismicity of the Intermountain seismic belt, *in* Slemmons, D.B., Engdahl, E.R., Zoback, M.D., and Blackwell, D.D., editors, Neotectonics of North America: Geological Society of America, Decade Map Volume 1, p. 185-228.

15 - Love

By Kimm Harty and Bill Black

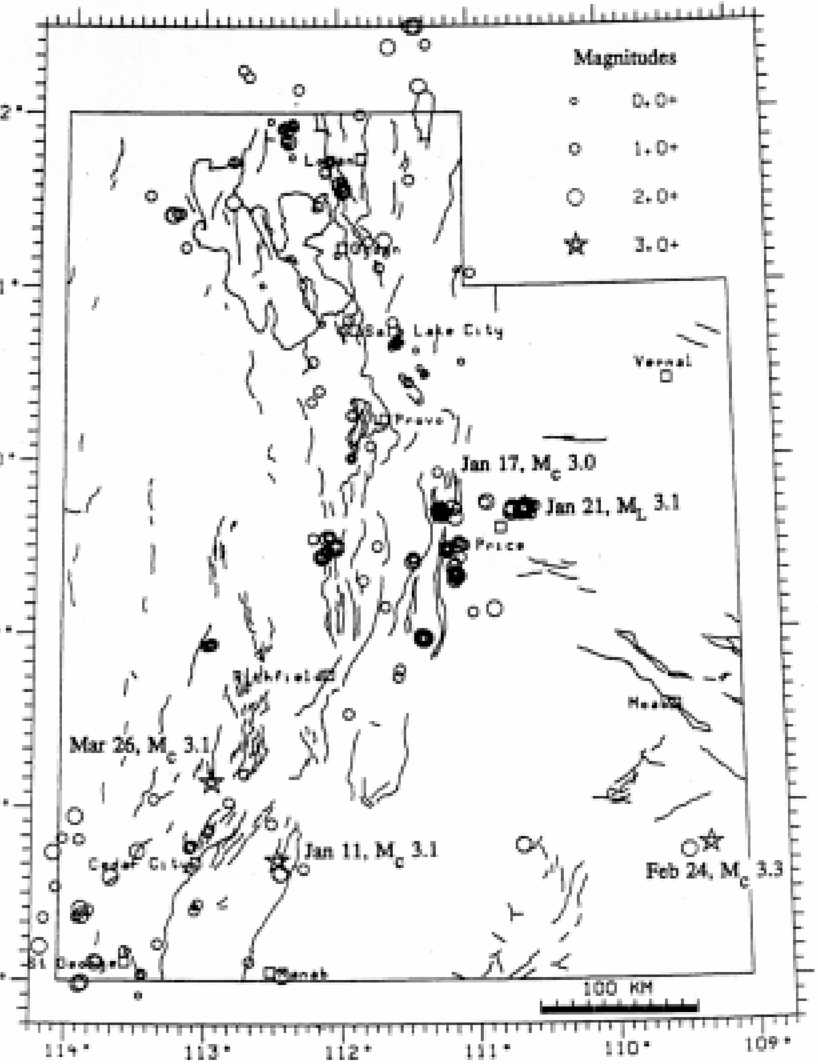
In early March of 1994, a large rock-fall boulder bounced down the mountainside in Olympus Cove south of Mill Creek Canyon in Salt Lake County. No injuries were sustained, but the 5 x 4.5 x 4.5 foot boulder tore through a chain-link fence and concrete retaining wall of a private residence before bouncing onto and coming to rest on a tennis court. The boulder dislodged from an outcrop of Pennsylvanian-age Weber Quartzite approximately 1,360 feet above the elevation of the residence. The boulder took a sinuous path down the mountain, leaving a scar of sheared oak brush and trees. Long-term weathering processes combined with springtime freeze-thaw activity likely triggered the rock fall. It occurred within a known rock-fall hazard area, and additional rock falls can be expected in this area in the future.





Earthquake activity in the Utah region

University of Utah Seismograph Stations,
Department of Geology and Geophysics
Salt Lake City, UT 84112-1183
(801) 581-6274
Additonal information on earthquakes within the Utah region is available from the University of Utah Seismograph Stations.



January 1 - March 31, 1993

During January 1 through March 31, 1993, the University of Utah Seismograph Stations located 367 earthquakes within the Utah region. The total includes five earthquakes in the magnitude 3 range and 177 in the magnitude 2 range. Earthquakes with magnitude 3.0 or larger are plotted as stars and specifically labeled on the epicenter map. There were two earthquakes reported felt during the report period. Magnitude indicated here is either local magnitude, M_L, or coda magnitude, M_C. All times indicated below are Mountain Standard Time.

Significant main shocks and clusters of earthquakes

• Eastern Wasatch Plateau-Book Cliffs area near Price (coal-mining related): Five clusters of seismic events (magnitude 0.9 to 3.3) make up 51% of the shocks that occurred in the Utah region during the report period. These clusters are located: (a) 10 miles NE of Price, (b) 25 miles WNW of Price, (c) 20 miles WSW of Price, (d) 25 miles SW of Price, and (e) 35 miles NE of Richfield.

M_C 3.0	January 17	12:26 p.m.	Part of cluster (b)
M_L 3.1	January 21	2:01 a.m.	Part of cluster (a)
			Felt in Helper and in Soldier Creek Mine

• Northern Utah: A cluster of 17 earthquakes occurred WNW of Garland (approximately 30 miles NW of Logan). The shocks occurred primarily in mid-January and in late March, and ranged in magnitude from 0.6 to 2.3.

Thirteen shocks occurred under the Wellsville Mountains, northeast of Brigham City, (approximately 30 miles NW of Logan). The earthquakes occurred sporadically throughout the report period.

A cluster of 14 earthquakes occurred primarily in March, three to five miles NW of Park City (20 miles ESE of Salt Lake City). The majority of these shocks had magnitudes less than 1.0.

• Central Utah: In early February and mid-March, a cluster of 17 earthquakes occurred SW of Levan (50 miles N of Richfield). The largest shock in this cluster was magnitude 2.8.

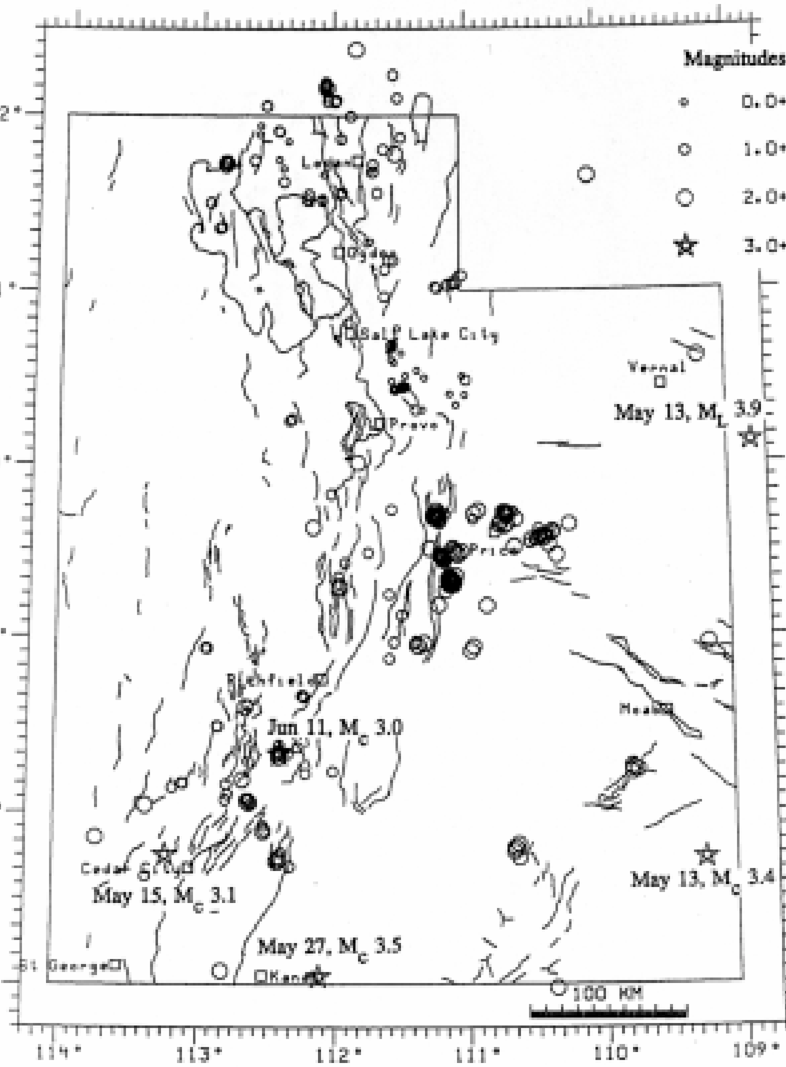
M_C 1.8	February 26	3:36 a.m.	3 miles NW of Payson, felt in Springville

• Significant earthquakes in Southern Utah:

M_C 3.1	January 11	8:34 p.m.	10 miles S of Panguitch
M_C 3.3	February 24	1:11 p.m.	7 miles SSE of Monticello
M_C 3.1	March 26	9:49 a.m.	5 miles S of Minersville

April 1 - June 30, 1993

During April 1 through June 30, 1993, the University of Utah Seismograph Stations located 405 earthquakes within the Utah region. The total includes five earthquakes in the magnitude 3 range and 186 in the magnitude 2 range. Earthquakes with magnitudes of 3.0 or larger are plotted as stars and specifically labeled on the epicenter map. There was one earthquake reported felt during the report period. Magnitude indicated here is either local magnitude, M_L, or coda magnitude, M_C. All times indicated below are local time, which was Mountain Standard Time from April 1-3, and Mountain Daylight Time during the remainder of the report period.



Significant main shocks and clusters of earthquakes

• Eastern Wasatch Plateau-Book Cliffs area near Price (coal-mining related): Five clusters of seismic events (magnitude 1.1 to 2.9) make up 49% of the shocks that occurred in the Utah region during the report period. These clusters are located: (a) 20 miles E of Price, (b) five miles NE of Price, (c) 25 miles WNW of Price, (d) 25 miles SW of Price, and (e) 30 miles SSW of Price.

• Northern Utah: A cluster of ten earthquakes occurred primarily in April and May, 5 miles WNW of Dayton, Idaho (30 miles NNW of Logan). The largest was a magnitude 2.5 shock.

In early April and late May, a series of six earthquakes from 1.1 to 2.1 magnitude occurred near the northern arm of the Great Salt Lake 35 miles W of Tremonton (50 miles W of Logan). This region was the site of Utah's only historical surface-faulting earthquake, a magnitude 6.6 shock that occurred on March 12, 1934.

In April and May, seven small earthquakes (magnitude 1.1 to 1.7) occurred near the Utah-Wyoming border, 15-20 miles NE of Coalville (40 miles NE of Salt Lake City).

Throughout the report period, a series of earthquakes occurred five miles S of Midway (15 miles NE of Provo), in the general vicinity of Deer Creek Reservoir. The shocks ranged in magnitude from 0.4 to 1.7.

• Eastern Utah region: M_L 3.9 May 13 10:13 a.m. 12 miles SE of Dinosaur, CO

• Southern Utah: Several small swarms of earthquakes occurred in southern Utah during the report period. In early April, five shocks (magnitude 1.2 to 2.7) occurred five miles SE of Panguitch (35 miles E of Cedar City). On June 16, a brief flurry of seven earthquakes (magnitude 1.4 to 2.7) occurred 15 miles SSE of Beaver (30 miles NE of Cedar City). In mid-June, nine shocks (magnitude 1.4 to 3.0) occurred 15 miles NE of Beaver (30 miles SW of Richfield). Significant earthquakes:

M_C 3.4	May 13	2:50 p.m.	10 miles SSE of Monticello
M_C 3.1	May 15	9:30 p.m.	11 miles WNW of Cedar City,felt in Cedar City
M_C 3.5	May 27	12:21 p.m.	23 miles E of Kanab
M_C 3.0	June 11	6:07 a.m.	13 miles NW of Circleville

New Utah Minerals

Compiled by Chris Kelson

This is a new column to appear in Survey Notes. For each issue, the Geologic Extension Service will describe new minerals discovered in Utah.

Cannonite $Bi_2O(OH)_2SO_4$. Cannonite is a bismuth hydroxide sulfate found in the Tunnel Extension mine, Ohio mining district, Piute County. It is a rare mineral associated with quartz gangue and is characterized by colorless, transparent crystals. The mineral has an adamantine luster and is brittle, with uneven to conchoidal fracture. Associated minerals include cuprobismutite, bismuthinite, and covellite. Cannonite was named for B. B. Cannon, who first recognized the mineral.
Miscellaneous data: hardness: 4; density: 6.515 g/cm^3

Fangite Tl_3AsS_4. Fangite is a thallium arsenic sulfosalt found at the Mercur gold deposit in the southern Oquirrh Mountains of Tooele County. It forms in vugs with pyrite and other sulfide material of complex composition. Fangite exhibits a deep-red to maroon color, and although no streak was obtained from natural fangite, synthetic fangite has an orange streak. Fangite is translucent but tarnishes to a nearly metallic luster. Crystals have relatively flat surfaces and conchoidal fracture. Associated minerals include realgar, orpiment, pyrite, and other sulfides. Fangite was named for Jen-Ho Fang in honor of his numerous contributions to crystallography, crystal chemistry, and geostatistics.
Miscellaneous data: hardness: 2.0-2.5; density: 6.185 g/cm^3

Gillulyite $Tl_2(As,Sb)_8S_{13}$. Gillulyite is one of several thallium minerals that are found in the Mercur gold deposit, Tooele County. It is found in vuggy masses of barite, in barite and calcite veins, and in the silty, carbonaceous limestone host rock. Gillulyite has a deep-red color and a red streak. It is translucent but tarnishes rapidly to a darker red or blue. Gillulyite forms very small, slender, prismatic crystals and has one perfect cleavage that is obvious on all specimens. Associated minerals are barite, calcite, orpiment, realgar, lorandite, raguinite, and pyrite. The mineral was named in honor of the late James C. Gilluly, author of the U.S. Geological Survey Professional Paper 173, *Geology and Ore Deposits of the Fairfield and Stockton Quadrangles, Utah.*
Miscellaneous data: hardness: 2.0-2.5; density: 4.022 g/cm^3 (meas)

Tooeleite $Fe_{8-2x}[(As_{1-x}S_x)O_4]_6 \cdot 5H_2O$. Tooeleite is found on waste dumps of the former gold and arsenic mine in the Gold Hill district, western Tooele County. Oxidation of the quartz-diopside host rock produced massive scorodite (a lesser ore of arsenic) containing voids, some lined with jarosite, and both minerals are coated with tooeleite crusts up to 10 mm thick. Tooeleite crystals form elongate blades up to 1 cm, and are translucent with a greasy luster. Hand specimens are orange with an orange streak. The name is derived from the locality.
Miscellaneous data: hardness: 3; density: 4.238 g/cm^3 (meas)

REFERENCES

Jambor, J.L., and Burke, E.A.J., 1993, New Mineral Names: American Mineralogist, v. 78, nos. 7 and 8, p. 845.

Wilson, J.R., Gupta, P.K.S., Robinson, P.D., and Criddle, A.J., 1993, Fangite, Tl_3AsS_4, a new thallium arsenic sufosalt from the Mercur Au deposit, Utah, and revised optical data for gillulyite: American Mineralogist, v. 78, nos. 9 and 10, p. 1096.

Wilson, J.R., Robinson, P.D., Wilson, P.N., Stanger, L.W., and Salmon, G.L., 1991, Gillulyite, $Tl_2(As,Sb)_8S_{13}$, a new thallium arsenic sulfosalt from the Mercur gold deposit Utah: American Mineralogist, v. 76, p. 653.

Wilson, J.R., and Wilson, P.N., 1990, Occurrence and paragenesis of thallium sulfosalts and related sulfides at the Barrick Mercur gold mine, Utah: Utah Geological Association Publication, no. 18, p. 78.

The Rockhounder

Sunstones at Sunstone Knoll, Millard County

By Christine M. Wilkerson

THE ROCKHOUNDER is a new column to appear regularly in Survey Notes. Each issue, Christine Wilkerson of the Geologic Extension Service will highlight an interesting Utah rock or mineral, and provide information on where and how to collect it.

Geologic information: Sunstone Knoll is formed of volcanic vents that erupted during the early Pleistocene (1.6 million years to about 750,000 years ago). These eruptions left deposits of basaltic lava and volcanic breccia (angular, broken rock fragments held together in a matrix of finer grained material). Sunstone is a transparent, yellowish labradorite (a plagioclase feldspar mineral) found as crystals in these volcanic rocks and on the flats surrounding the knoll.

Sunstones collected at Sunstone Knoll. Stones range from 1/4 to 3/4 inch long.

Where to collect: Sunstones litter the ground on the east side of the knoll. Many small stones can easily be found when they glitter in the sunlight. Stones range from 1/8 to nearly 1 inch long, but the larger stones are rare. Crystals and fractured grains of sunstone can also be found in cavities in the lava although the rocks generally have to be broken to expose the crystals.

How to get there: From the west edge of the town of Delta (railroad overpass), travel west on U.S. Highway 6/50 about 4.3 miles to the State Highway 257 junction. Turn south on highway 257 and travel approximately 13.4 miles (just before milemarker 56). A sign on the west side of the road marks the entrance to Sunstone Knoll on the east. Turn east onto the dirt road, cross the railroad tracks (watch for trains), and circle around the knoll to the east side. Please sign the register at the entrance. A private claim is on part of this site, but individuals are generously allowed to collect.

Useful maps: Utah highway map, Delta 1:100,000-scale topographic map, and Sunstone Knoll topographic map (7.5 minute).

Land ownership: Private mining claim and BLM public lands.

Precautions, miscellaneous: Children should have an easy time collecting on the flats, but be careful, as glass from broken bottles can easily be mistaken for glittering sunstone. Watch for rattlesnakes. Look for trains before crossing the railroad tracks. A hat and water are recommended. Bring a rock hammer and protective eyewear if you intend to break open the rocks. Please carry out your trash. Have fun collecting!

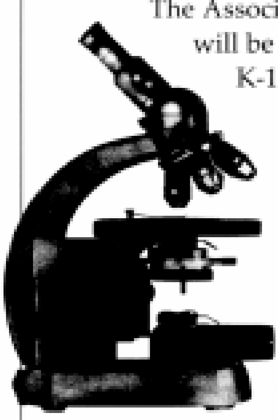
Sunstones litter the ground on the flats east of Sunstone Knoll. This rockhound is collecting numerous stones.

A private mining claim is located on part of this site, but individuals are allowed to collect and are asked to sign the register located at the entrance to the knoll. (View of southern Sunstone Knoll area in background).

Teacher's Corner

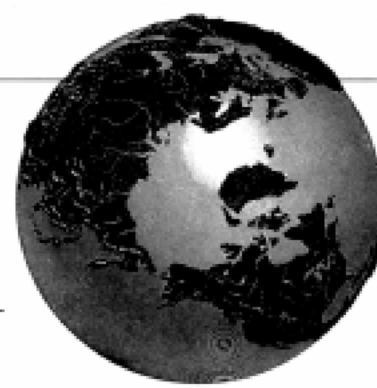
by Sandy Eldredge

TEACHER AWARD



The Association of Women Geoscientists will be offering an award this year to a K-12 teacher of Earth Science or related field. The award will be made to a teacher demonstrating a need for financial assistance to further their goals as an Earth Science teacher. Check your science newsletter from the State Office of Education for an announcement this summer.

GLOBAL CHANGE



A new informative poster and activity packet for teachers available from the U.S. Geological Survey focuses on four themes: time, change, cycles, and Earth as home. For a packet, contact the Branch of Publications, U.S. Geological Survey, 508 National Center, Reston, VA 22090 or call 1-800-USA-MAPS.

Rules and regulations regarding rock and mineral collecting in Utah

by Geologic Extension Service Staff

Utah's rock and mineral collectors must adhere to rules and regulations established by owners of the lands on which they wish to collect. Prior to collecting, rockhounds should determine ownership of the lands they intend to visit and familiarize themselves with the regulations that apply to collecting on those lands. Utah's lands are managed by the federal government (Bureau of Land Management, U.S. Forest Service, National Park Service, or the Bureau of Indian Affairs), state government (Utah Division of Sovereign Lands and Forestry), and private owners (including local governments). Rockhounding permits are required to collect on some government lands, and permission is required to collect on private lands.

FEDERAL LANDS

About 67 percent of Utah's lands are managed by the federal government. Most of this land is open to collecting except for National Parks, National Monuments, Indian Reservations, military reservations, dam sites, and wildlife refuges.

Bureau of Land Management (BLM) Lands: The casual rockhound or collector may take small amounts of petrified wood, fossils, gemstones, and rocks from unrestricted federal lands in Utah without obtaining a special permit if collection is for personal, non-commercial purposes. Collection in large quantities or for commercial purposes requires a permit, lease, or license from the BLM.

Collectors of petrified wood on BLM land are subject to slightly different rules. Collecting for personal use has a maximum limit of 25 pounds plus one piece per day but cannot exceed more than 250 pounds per calendar year. Use of explosives and/or power equipment is forbidden. Collectors wishing to resell their petrified wood specimens must apply for a permit.

National Parks and Native American Lands: Collecting on National Park Service or Native American lands is prohibited.

U.S. Forest Service Lands: Rock and mineral collecting on lands managed by the U.S. Forest Service requires a permit. Although collecting is allowed in most districts and permits are free, collecting rules vary among districts.

STATE LANDS

State-owned properties are managed by the Division of Sovereign Lands and Forestry, and a Rockhounding Permit is required to collect on these lands. The annual permit costs $5 for individuals or a family, and $200 for an association/organization. With the permit, rockhounds may collect up to 25 pounds plus one piece per person per day, up to a maximum of 250 pounds per year. Collectors cannot operate in state and local parks.

To remove rock and mineral specimens from state lands, commercial collectors must also follow specific regulations, and apply to the Utah Division of Sovereign Lands and Forestry for mineral leases. Materials such as building stone, limestone, gemstones, and volcanic materials are commonly collected by amateur collectors but require leases for commercial collectors.

PRIVATE LANDS

To access or collect on privately owned lands, collectors must contact and obtain permission from the owners prior to entering the property.

NOTE : These rules and regulations do not apply for fossil collecting. For rules governing fossil collecting in Utah, contact the office of the State Paleontologist at 300 Rio Grande, Salt Lake City, UT, 84101, (801)533-3513.

SAFETY TIPS

Rockhounding can be a potentially dangerous hobby. To minimize the risk of injury, please remember:

- Wear protective equipment (safety glasses, gloves, boots).
- Do not work alone, and let some one else know your schedule.
- Carry a first aid kit.
- Watch for others, and when on hillslopes, never work directly above or below anyone.
- Do not enter abandoned mines or shafts.

Survey News

The Dibblee Award

Dr. Lehi F. Hintze, a senior geologic mapper for the Utah Geological Survey and Professor Emeritus of Geology at Brigham Young University, received the 1994 Dibblee Medal Award for outstanding geologic mapping achievements.

An internationally known expert on Utah geology, Hintze has authored or co-authored more than 50 geologic maps. He compiled the 1980 "Geologic Map of Utah," considered the definitive work on Utah geology.

Dr. Hintze played a key role in establishing Utah's geologic mapping program, which is the third largest in the country. He also wrote the book "Geologic History of Utah," a standard reference for Utah geologists and a best seller among the public at national and state parks.

In addition to his accomplishments as a geologic mapper, Dr. Hintze has established an outstanding record as a university professor. Last year he received the Utah Governor's Medal for Science and Technology.

The Thomas Wilson Dibblee Jr. Geological Foundation sponsors the Dibblee Medal to honor the extraordinary mapping achievements of Tom Dibblee, a California geologist who published more than 600 geologic maps.

Mike Hylland is the new staff geologist in the Applied Geology group at the Utah Geological Survey. He received his bachelor's degree in geology in 1985 from Western Washington University, and his master's degree in geology in 1990 from Oregon State University. Mike's thesis work took him to northern Pakistan to map bedrock geology in the Himalayan foothills. While completing his graduate studies, Mike worked for a year as an engineering geologist for the U.S. Forest Service in Washington State. Mike later spent 3 ½ years working as an engineering geologist with a geotechnical consulting firm in the Seattle area.

UGS wins award

The Utah Geological Survey was selected by Hart's *Oil and Gas World* magazine to receive an award for Best Field Improvement Project in the Rocky Mountain region in 1993. The award was part of the magazine's third annual "Best of the Rocky Mountains" competition.

The Survey was honored for an advanced study of techniques to improve oil recovery in the Bluebell oil field in Uintah and Duchesne Counties. The project is funded by the U.S. Department of Energy. Quinex Energy Company of Bountiful, Utah, received a certificate of achievement for its role in the project.

"This award recognizes the unique cooperation between industry, government, and universities in Utah," said M. Lee Allison, Director, Utah Geological Survey. "Ultimately, this project could lead to the additional production of hundreds of millions of barrels of oil in the Uinta Basin."

The project was chosen by a panel of four judges, two each from the Independent Petroleum Association of Mountain States and the New Mexico Oil and Gas Association.

STATEMAP Grant

The U.S. Geological Survey approved the Utah Geological Survey proposal to map three quadrangles under STATEMAP component of the National Geologic Mapping Program. The award of $38,000 will be matched by the UGS to map the St. George, Washington, and Moab quadrangles, areas recommended by the State Mapping Advisory Committee, that are undergoing rapid urban development or are being heavily impacted by tourists. A good understanding of the geology in these fast-growing areas will be essential for proper planning.

Christine Wilkerson is the new geologist with the Geologic Extension Service (GES). She has worked for the Utah Geological Survey for over 6½ years, the last five as the geological technician with the Information Section (predecessor of the GES). Chris has a B.S. degree in geology from the University of Utah.

Public-access computer now available at the UGS

Part of the mission of the Utah Geological Survey (UGS) is to make available to a wide range of users geologic information obtained by, compiled by, or produced by the UGS. To achieve this goal, we have recently made available a public-access computer that contains over a dozen databases dealing primarily with Utah geology. The personal computer is located in the UGS library, its use is free-of-charge, and it is available for use 8:00-5:00 p.m., Monday through Friday.

Most of the databases will be updated regularly, and more are planned for installment onto the public-access machine. The following list provides details on the current databases.

Utah Geological Survey Databases

AMRMGR - Funded by the Gas Research Institute, the AMRMGR (Atlas of Major Rocky Mountain Gas Reservoirs) database contains a summary of geologic and reservoir data for the major gas fields in Colorado, New Mexico, Utah, and Wyoming. The database uses a menu-driven interface that allows users to search or browse through the database. AMRMGR can be searched by field name, producing formation, and other geologic and reservoir parameters. The database is available for purchase in hard-copy format at the UGS (Atlas of major Rocky Mountain gas reservoirs).

HAZBIB - HAZBIB is a bibliography of Utah's geologic hazards. It contains references of both published and unpublished material. Types of geologic-hazard references in the bibliography include: earthquakes, landslides, problem soils, flooding, shallow ground water, and radon. HAZBIB uses a menu-driven interface that allows users to search the database for references by author, title of reference/publisher, or by key words (subject and location). An ASCII file of HAZBIB data is available for purchase (UGS Open-File Report 264-DF).

INTEGRAL - INTEGRAL is a menu-driven database that manages UGS surface and subsurface point-source geologic data. Most of the records in the database are petroleum exploration wells, and examples of data in the database include: bore-hole location, geophysical logs, geologic formations, age dates, oil and gas production, and more. INTEGRAL is written in Paradox Application Language (PAL) and is accessed through Windows. Although currently functioning, much data still remains to be entered into the database. INTEGRAL is sure to become the most popular database at the UGS.

MAPBIB - MAPBIB is a bibliography of geologic maps of Utah. The database includes both published and unpublished geologic-map references. It uses a menu-driven interface that allows users to search or browse the database. Searches can be performed by map author, title, publication, map scale, and location.

UGS Library Card Catalog - This database is a bibliography of non-journal publications housed in the UGS Library. It uses a menu-driven interface that allows the users to search or browse through the database. The user can search for publication references by card-catalog number, author, title of publication, or by using key words.

UMOS - Utah Mineral Occurrences is a list of mines and mineral occurrences on the Cedar City, Delta, Richfield, and Tooele 1x2 degree maps (scale 1:250,000). The user must know Rbase v.2.11 database manager to search or browse through the database. An ASCII file of the UMOS data for each of the 1x2 degree maps listed above is available for purchase (UGS Open-File Reports 153-DF, 183-DF, 184-DF, and 185-DF).

URANIUM - This database contains approximately 2,500 uranium assays sampled from outcrops and mine tailings throughout Utah. Data is presented in raw form and users must be familiar with Quattro Pro software to browse the database.

Utah Coal Data - Utah Coal Data consists of four databases containing physical and chemical characteristics of Utah coal. COALBC and COALWP databases store data from the Book Cliffs and Wasatch Plateau coal fields, respectively; FERRON contains data from Ferron Sandstone coals in the Uinta Basin; and COLMISC contains data from coal fields in other areas of Utah. Users must know Rbase v.2.11 database manager to search or browse through the database.

U.S. Geological Survey Databases

Utah Geographic Names - This database contains names of geographic features in Utah (for example, lakes, rivers, valleys, summits). It uses a menu-driven interface that allows users to search the database by the name of the feature, the feature type, or by feature location (7.5' topographic quadrangle).

GNULUX - GNULUX is the digital version of the Lexicon of Geologic Names on CD-ROM. It uses a menu-driven interface that allows the user to search for geologic formation names by region of the United States. GNULUX is also available for purchase through the U.S. Geological Survey (USGS DDS-6).

Nevada Geologic Map - This database contains the digital geologic map of Nevada on CD-ROM. The CD-ROM containing the Nevada geologic map is available for purchase through the U.S. Geological Survey (USGS DDS-2).

Colorado Core - This is a database of petrophysical properties and images of selected drill core from Colorado and Utah on CD-ROM. Cores are from northwest Colorado and the Paradox basin of Colorado and Utah. Colorado Core CD-ROM is available through the U.S. Geological Survey (USGS Open-File Report 91-355).

NURE - NURE (National Uranium Resource Evaluation) includes geochemical analyses of uranium, sulfate, and 58 other elements from stream sediments, soils, surface water, and ground water in the coterminous western United States. The data were collected during the hydrochemical and stream sediment reconnaisance program from 1976 to 1980. The database contains nearly 400,000 records and is on CD-ROM. The NURE CD-ROM is available through the U.S. Geological Survey (USGS DDS-1).

Utah Geological Survey receives three 1994 NEHRP Grants

The U.S. Geological Survey recently announced that three Utah Geological Survey (UGS) proposals were selected for funding in 1994 under the National Earthquake Hazards Reduction Program. The proposed projects cover a wide range of topics, from evaluating faults and liquefaction-induced landslides along the Wasatch Front to producing timely, "translated" earthquake information and databases.

One project is entitled "Seismic source evaluation of the Salt Lake City segment of the Wasatch fault zone, central Wasatch Front, Utah" ($27,680 federal cost-share). The UGS will reoccupy an earlier trench site in Sandy (the South Fork Dry Creek site) on the Salt Lake City segment of the Wasatch fault zone to complete the paleoseismic investigation started there in 1985. The goal is to establish the history of Holocene surface faulting at a single location on the Salt Lake City segment. By combining the results of this investigation with those obtained in 1985, construction of a more complete chronology of surface-rupturing earthquakes for the segment from at least the middle Holocene (6,000 years ago to the present) should be possible. Until that chronology is established with confidence, questions will remain regarding the seismic history of Utah's most populous fault segment and the adequacy of hazard and risk assessments currently used to prepare for future large earthquakes.

The second project is entitled "Hazard potential, failure type, and timing of liquefaction-induced landsliding in the Farmington Siding landslide complex, Wasatch Front, Utah" ($19,134 federal cost-share). This project is a detailed geologic investigation of the landslide complex near Farmington. A recent NEHRP-funded study by the UGS confirmed that recurrent movement has taken place. However, the timing of landslide events and mechanism of movement (flow failure versus lateral spreading) have not yet been clearly determined. These factors must be understood to evaluate hazard potential so that local governments can determine how to approach land use on the landslide. In addition to helping assess hazards in the Farmington area, methods developed in this study may prove valuable for evaluating similar problems on other landslides along the Wasatch Front and elsewhere.

The final project is entitled "Effective dissemination of NEHRP research results in Utah—connecting researchers and practitioners" ($15,850 federal cost-share). The UGS continues an active program to translate scientific research results for nontechnical users, and to forge partnerships between the research community (universities, the private sector, and state and federal agencies) and those who use the information to implement hazard-reduction policies (local governments, engineers, architects, planners, and emergency planners and responders). In this project, we will apply geographic information systems (GIS) methods to consolidate the recently completed Quaternary tectonics map and tabular database. We will also expand and update the Geologic-Hazards Bibliography of Utah and publish the Fault Line Forum (formerly the Wasatch Front Forum) to more effectively disseminate earthquake-hazards information.

New Publications of the UGS

Bulletins

Allosaurus fragilis: a revised osteology, by J.H. Madsen, Jr., 1976, 163 p., (REPRINT) **$9.00**

Quaternary tectonics of Utah with emphasis on earthquake-hazard characterization, by Suzanne Hecker, 157 p., 2 pl., 1:500,000, 1993, B-127 .... **$16.00**

Map Series

Geologic map of The Barracks quadrangle, Kane County, Utah, by E.G. Sable and H.H. Doelling, 11 p., 2 pl., 1:24,000, 1993, M-1477 .... **$6.00**

Quaternary geologic map of Skull Valley, Tooele County, Utah, by Dorothy Sack, 16 p., 1 pl., 1:100,000, 1993, M-150 .... **$6.00**

Geologic map of the Bear River City quadrangle, Box Elder County, Utah, by M.E. Jensen, 12 p., 2 pl., 1:24,000, 1994, M-151 .... **$6.00**

Provisional geologic map of the Hatch Mesa quadrangle, Grand County, Utah, by J.P Chitwood, 16 p., 2 pl., 1:24,000, 1994, M-152 .... **$6.00**

Geologic map of the Shivwits quadrangle, Washington County, Utah, by L.F. Hintze and B.J. Hammond, 21 p., 2 pl., 1:24,000, 1994, M-153 .... **$6.00**

Quaternary geologic map of the upper Weber River Basin drainage, Summit County, Utah, by C.G. Oviatt, 10 p., 1 pl., 1:50,000, 1994, M-156 .... **$6.00**

Special Study

Neotectonic deformation along the East Cache fault zone, Cache County, Utah, by J.P. McCalpin, 37 p., 1994, SS-83 .... **$5.00**

Miscellaneous Publications

Site-specific strong ground motion estimates for the Salt Lake Valley, by I.G. Wong and W.J. Silva, 34 p., November 1993, MP-93-9 .... **$ 5.50**

Oil & Gas Field Study

Oil and gas production maps of the Bluebell Field, Duchesne and Uintah Counties, Utah, by C.D. Morgan, 5 p., 8 pl., 1"= 0.8 mile, January 1994, OG-15 .... **$10.00**

Public Information Series

Geologic resources of Washington County, Utah, by Miriam Bugden, 26 p., 12/93, PI- 20 .... **$2.00**

Radon-hazard potential in the Provo-Orem area, Utah County, Utah, by Barry Solomon, 1 p., 9/93, PI-21 .... **FREE**

Open-File Report

Interim geologic map of the Bear Lake South quadrangle, Rich County, Utah, by J.C. Coogan, 54 p., 4 pl., 1:24,000, 3/94, OFR-303 .... **$10.35**

Interim geologic map of the Sheeppen Creek quadrangle, Rich County, Utah, by J.C. Coogan, 51 p., 4 pl., 1:24,000, 3/94, OFR-304 .... **$10.15**

Interim geologic map of the Smithsonian Butte quadrangle, Washington County, Utah, by D.W. Moore and E.G. Sable, 79 p., 1 pl., 1:24,000, 3/94, OFR-305 .... **$8.35**

Contract Report

Earthquake hazard evaluation of the West Valley fault zone in the Salt Lake City urban area, Utah, by J.R. Keaton and D.R. Currey, 69 p., Oct. 1993, CR-93-8 .... **$5.60**

Paleoseismicity and earthquake hazards evaluation of the West Valley fault zone, Salt Lake City urban area, Utah, by J.R. Keaton, D.R. Currey, and S. J. Olig, 55 p., plus 33 p. appendix, Oct. 1993, CR-93-8 .... **$7.00**

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Recent Publications of Interest

(Not available from UGS)

Applications of research from the U.S. Geological Survey program, assessment of regional earthquake hazards and risk along the Wasatch Front, Utah, edited by P.L. Gori, U.S. Geological Survey, 1993, 167 p., USGS P-1519.

Analytical results for soil samples collected at the Roosevelt Hot Springs Known Geothermal Resource Area, Utah 1976-1987, by M.E. Hinkle, 1993, 14 p., one 5 ¼ inch diskette, USGS Open-File Report 93-0260.

Surficial geologic map of the Weber Segment, Wasatch fault zone, Weber and Davis Counties, Utah, by A.R. Nelson and S.F. Personius, 1993, 1:50,000, 1 sheet accompanied by 22 p. text, USGS I-2199.

A high-resolution seismic reflection and gravity survey of Quaternary deformation across the Wasatch Fault, Utah, by W.J. Stephenson, R.B. Smith and J.R. Pelton. Journal of Geophysical Research, B, Solid Earth and Planets, v. 98, no. 5, May 10, 1993, p. 8211-8223.

Multifaceted studies of a lacustrine source rock, the Paleogene Green River Formation, Colorado, Utah, and Wyoming, by M.L. Tuttle, W.E. Dean, M.R. Stanton, James Collister, W.J. Harrison, T.D. Fouch, J.K. Pitman, Trond Hanesand and Nils Telnaes, p. 20., (abs.) USGS OFR-92-391.

Preliminary geologic map of Navajo Lake Quadrangle, Kane and Iron Counties, Utah, by D.W. Moore and N.L. David, 1993. 20 p., 1 over-size sheet, 1:24,000, USGS Open-File Report 93-0190.

Pennsylvanian and Early Permian paleogeography of the Uinta-Piceance Basin region, northwestern Colorado and northeastern Utah, by S.Y. Johnson, M.A. Chan, and E.A. Konopka, 1992, p. CC1-CC35, USGS Bulletin 1787-CC.

Phanerozoic evolution of sedimentary basins in the Uinta-Piceance Basin region, northwestern Colorado and northeastern Utah, by S.Y. Johnson, 1992, p. FF1-FF38, USGS Bulletin 1787-FF.

Preliminary geologic map of the Low Peak 7½-minute quadrangle, Tooele, Utah, and Salt Lake Counties, Utah, compiled by E. W. Tooker, 1992, 13 p., 1 over-size sheet, 1:24,000, USGS Open-File Report 92-0404.

Surficial geologic map of the Wasatch fault zone, eastern part of Utah Valley, Utah County and parts of Salt Lake and Juab Counties, Utah, by M.N. Machette, 1992, 1:50,000, USGS I-2095.

Controls on the accumulation of coal and on the development of anastomosed fluvial systems in the Cretaceous Dakota Formation of southern Utah, Sedimentology, v. 39, no. 4, August, 1992, p. 581-598.

Geometry and structural evolution of gilsonite dikes in the eastern Uinta Basin, Utah, by E.R. Vereek and M.A. Grout, 1993, p. HH1-HH42, 1 plate in pocket, USGS Bulletin 1787-HH.

Geologic map of the Parowan Gap Quadrangle, Iron County, Utah, by Florian Maldonado and V.S. Williams, 1993, 1:24,000, USGS GQ-1712.

Geologic map of the Paragonah Quadrangle, Iron County, Utah, by Florian Maldonado and V.S, Williams, 1993, 1:24,000, USGS GQ-1713.

Geologic map of the Dodge Spring Quadrangle, Washington County, Utah, and Lincoln County, Nevada, by R.E. Anderson and L.F. Hintze, 1993, 1:24,000, USGS GQ-1721.

Seepage study of the Bear River including Cutler Reservoir in Cache Valley, Utah and Idaho, by L.R. Herbert and B.K. Thomas, State of Utah, Department of Natural Resources, Report no. 105, 1992, 18 p.

Physical extent, recharge areas, relative potential for recharge and contamination, and quality of water in the principal aquifers, western Kane County, Utah, by L.E. Spangler, G.W. Freethey and G.A. Green. 1993, USGS WRI 92-4070.

Maps showing recharge areas and quality of ground water for the Navajo Aquifer, western Washington County, Utah, by G.W. Freethey, 1993, 1 over-size sheet, 1:24,000 and 1:375,000, USGS WRI 92-4160.

Laramide basement deformation in the Rocky Mountain Foreland of the western United States, edited by C.J. Schmidt, R.B. Chase, and E.A. Erslev, 1993, 365 p., 4 pl. (plate 2 is in 3 parts), Geological Society of America Special Paper 280.

As a long-time, although former, resident of the foreland, I appreciated the collection of many significant papers in this publication. It will undoubtedly become part of my library, and I would recommend its purchase to any student of foreland tectonics. What most impressed me was the quality and quantity of the illustrations, and Don Stone's plates. In a visual science like geology, the figures helped me comprehend new ideas and return to old friends (vistas, outcrops, seismic lines, concepts).

Any niggling problem I encountered shows my roots. The dedications were intriguing, considering the dominance of horizontal compression papers; at least the editors immediately noted Blackstone and Berg in the preface. I realize that GSA published a Bill Brown-authored foreland summary only five years ago (Memoir 171), but for completeness a Bill Brown perspective seemed appropriate. As a substitute, Eric Erslev's summary was an excellent choice. In contrast, the inclusion of some of the papers left me wondering why other work was absent. Finally, a point only a long-term researcher would notice: previous maps and reports on some sites in Wyoming weren't cited, so that maps and ideas seemingly presented for the first time are, at best, repetitions.

Despite these shortcomings, the book's a buy. *John K. King*

Geologic Projects in Utah Summary

1994

by Michael Ross

The 1994 summary of Geologic Projects in Utah contains 111 entries on a variety of geologic studies. The summary allows geologists working in the state to contact colleagues working on similar or interrelated studies. The summary of geologic projects contains information on: 1) investigator(s), 2) organization(s), 3) county(ies) in study area, 4) specific geographic or geologic location, 5) type of study, 6) title or topic of project, and 7) scale of geologic mapping (if applicable). Special searches can be made by investigator, county, type of study, and scale of mapping.

The UGS appreciates all responses received from non-UGS investigators, however, we know that the 1994 summary contains only a part of the total number of geologic projects currently underway in Utah. As a summary listing is consistently published on an annual basis, the UGS believes the number of responses from non-UGS investigators should increase. The listing shows the wide range of UGS projects currently underway or supported by the UGS.

The Geologic Projects in Utah information request form is published in the Fall issue of *Survey Notes* and the summary of responses is published in the next year's Spring-early Summer issue of *Survey Notes.*

Explanation for County codes

Beaver .... BE
Box Elder .... BX
Cache .... CA
Carbon .... CR
Daggett .... DG
Davis .... DA
Duchesne .... DU
Emery .... EM
Garfield .... GA
Grand .... GR
Iron .... IR
Juab .... JU
Kane .... KA
Millard .... MI
Morgan .... MO
Piute .... PI
Rich .... RI
Salt Lake .... SL
San Juan .... SJ
Sanpete .... SA
Sevier .... SE
Summit .... SU
Tooele .... TO
Uintah .... UI
Utah .... UT
Wasatch .... WS
Washington .... WA
Wayne .... WN
Weber .... WE
Statewide .... SW

Explanation for Type of Study codes

Economic Geology:
- a. General .... EC
- b. Coal .... CG
- c. Geolthermal .... GG
- d. Minerals .... MG
- e. Petroleum .... PG
- f. Salines .... SG

Engineering Geology .... EG
Environmental Geology .... EV
Geochemistry .... GC
Geochronology .... GR
Geologic Hazards .... GH
Geolgic Mapping .... GM
Geophysics .... GP
Hydrogeology .... HG
Mineralogy .... MN
Paleomagnetism .... PM
Paleontology:
- a. Undifferentiated .... PU
- b. Invertebrate .... PI
- c. Vertebrate .... PV

Palynology/Paleobotany .... PY
Quaternary Geology .... QG
Sedimentology .... SD
Stratigraphy .... SR
Structural Geology/Tectonics ... ST
Volcanology .... VO

Geologic Projects in Utah - 1994

(UGS) - Cooperative Funding

Investigator(s)	Organization(s)	County(s)	Location	Type of Study	Title / Top	Scale of Map
Allison, M. Lee	UGS	JU,MI,TO	Western Utah & B&R Trans. Zone	ST	In situ stress @ geothermal systems in B & R	-0-
Black, B.D., and Solomon, B.J.	UGS	CA,DA,TO	Cache & Tooele Valleys/Weber R	GH	Radon-hazard potential of the ... study areas	-0-
Blackett, Robert	UGS	SW	Statewide	GG	Utah geothermal database	-0-
Caputo, M.V.	San Antonio Col	EM,WN,GR	Colorado Plateau	SD,SR	Facies architecture of Middle Jurassic strata	-0-
Chidsey, T.C., & Anderson, P.B.	UGS	SW	Statewide	PG	Oil & gas pipeline map of Utah	1000000
Chidsey, T.C., and others	UGS & DOGM	SW	Oil and gas fields of Utah	PG	Utah oil sample bank/source rock study	-0-
Chidsey, T.C., and others	UGS,UURI,DOGM	SW	Case study - Duchesne field	PG	Increased prod. from directed horiz. drilling	-0-
Chidsey, T.C., and others	UGS & Harken En	SJ	Southeastern Utah	PG	Increased prod. using secondary/tertiary tech	-0-
Chidsey, T.C., and others	UGS and others	EM	San Rafael Swell & Coal Cliffs	PG	Geol. & petrophy. charact. of K Ferron ss	-0-
Christenson, G.E., and others	UGS	WA	SW Utah, Springdale area	GH	Effects of 9/2/92 St. George earthquake	-0-
Coco van den Bergh, T.C.V.	Wisconsin-Mad.	EM	Colo. Plat./San Rafael Swell	SR,SD	Seq. strat. & facies arch. of K Ferron ss.	-0-
Davis, F.D.	UGS	SL	Salt Lake Valley	GM,EC,GH	Geology of the Midvale quadrangle	24000
DeCelles, P., and Coogan, J.	Univ. Arizona	DA,MO,WE	Utah thrust belt	SD,SR,ST	Provenance, setting, & age synorogenic congl.	-0-
Doelling, H.H.	UGS	GR	N Paradox Bs/Salt Anticline Ar	GM	Geology of the Fisher Towers quadrangle	24000
Doelling, H.H.	UGS	GR	Colorado Plateau/N Paradox Bs	GM	Geology of the Klondyke Bluffs quadrangle	24000
Doelling, H.H.	UGS	GR	Arches Natl Park/N Paradox Bs	GM	Geology of the Mollie Hogans quadrangle	24000
Doelling, H.H.	UGS	GR	Eastern Utah/Colorado Plateau	GM	Geology of southern Grand Co., Utah	100000
Doelling, H.H.	UGS	GR	Arches Natl Park/ N Paradox Bs	GM	Geology of the Windows quadrangle	24000
Doelling, H.H., and Morgan, Craig	UGS	GR	Arches Natl Park/N Paradox Bs	GM	Geology of the Merrimac Butte quadrangle	24000
Doelling, H.H., and others	UGS	GR	N Paradox Bs/Salt Anticline Ar	GM,ST,SR	Geology of the Moab quadrangle	24000
Dubiel, R.F., and others	USGS	GR,SJ,GA	Colorado Plateau/Paradox basin	SR,SD,GM	P&Tr depositional systems & paleogeography	24000
Eldredge, Sandra	UGS	GR,SJ	Southeastern Utah/Canyonlands	-0-	Geologic guide to Canyonlands travel region	-0-
Eldredge, Sandra	UGS	SW	Statewide	GH	Homebuyers guide to earthquake hazards	-0-
Eldredge, Sandra	UGS	DA,SL,UT	Wasatch Front/northern Utah	GH	The Wasatch fault	-0-
Felger, T.	UM-Duluth(UGS)	JU	Juab Valley/W Gunnison Plateau	GM	Geology of the Skinner Peaks quadrangle	24000
Felger, T., and others	USGS (UGS)	JU	Southern Wasatch Mountains	GM	Geology of the Mona quadrangle	24000
Fiesinger, D.W.	USU	BX	Northwestern Utah	SR,PT,GR	T-Q volcanism in western Box Elder Co.	-0-
Gianniny, G.L., and Simo, T.	Wisconsin-Mad.	SJ	Paradox Bs/Goosenecks of SJR	SD,SR,PI	IP carbonate buildups & platform evolution	-0-
Goodknight, Craig	RUST Geotech	SJ	Colorado Plateau/Monticello	GM,HG,EG	Surface & groundwater invest. tailings site	1200
Gwynn, J.W.	UGS	GR,SJ	Colorado Plateau/Paradox basin	SG,GC	Saline waters of the Paradox basin	-0-
Harty, K.M., and Lowe, Mike	UGS	BX,WE,DA	Wasatch Front, northern Utah	GH,EG	Eval. of liquefaction-induced landslides	24000
Higgins, J., and Willis, G.	UGS	WA	St. George area	GM	Geology of St. George quadrangle	24000
Hintze, L.F., and Davis, F.D.	UGS	MI	Western Utah/Basin and Range	GM,EC,GH	Geology of Millard County, Utah	100000
Huffman, A.C., and others	USGS	GA,GR,SJ	SE Utah, SW Colorado	PG,SR,ST	Geologic evolution of the Paradox basin	-0-
Keith, J.D.	BYU (UGS)	JU,UT	Tintic Mountains	GM,PT,GC	Geology of the Tintic Mountain quadrangle	24000
King, J.K.	UGS	BX,CA	Northern Utah/Cache Valley	GM,EC,GH	Geology of the Clarkston quadrangle	24000
King, J.K.	UGS	BX,CA	Northern Utah/Clarkston Mtn.	GM,EC,GH	Geology of the Portage quadrangle	24000
King, J.K., and Jensen, M.E.	UGS	BX	Northern Utah/ Wasatch Mtns.	GM,EC,GH	Geology of Brigham City quadrangle	24000
Larson, Paul R.	Univ. of Utah	EM,SA	Central Utah/Wasatch Plateau	QG,GR	Glacial geomorphology of part of the WP	24000
Leatham, W. Britt	CSU-San Bernad.	RI	Northern Utah/Bear Lake basin	PI,SR	Quaternary gastropod paleoecology	-0-
Leatham, W. Britt	CSU-San Bernad.	MI,TO	Confusion Range/Silver Island	PI,SR	Conodont biostratigraphy of O & S rocks	-0-
Lowe, Mike	UGS	DA	Wasatch Mountains	GM	Geology of the Farmington quadrangle	24000
Lowe, Mike	UGS	SU	Wasatch Mountains	HG	Hydrogeology of the Snyderville Basin ...	-0-
Lowe, Mike	UGS	DA	Northern Utah, Wasatch Mtns	GH	Hazard potential of landslide complexes ...	24000
Lowe, Mike, and Hylland, Mike	UGS	WS	Wasatch Mountains & valleys	GH,EV,GM	Geohazards maps-Keetley, Heber, Round valleys	24000
Lund, W.R., and Black, B.D.	UGS	SL	Southern Salt Lake valley	GH	Seismic source eval. of SL seg. Wasatch fault	-0-
Mattox, Stephen R.	NIU (UGS)	WN	Central Utah / Awapa Plateau	GM,PT,VO	Geology of the Moroni Peak quadrangle	24000
Meyer, Charlie, and Nash, W.P.	Univ of Utah	GR,SJ	La Sal Mountains	PT,MN,GC	Pet.& geochem. of nosen-bearing rocks of ...	-0-
Miller, David	USGS	BX	Northeastern Basin & Range	GM,ST,SR	Geology of the Grassy Mountains area	50000
Miller, David	USGS	TO	Northeastern B&R/Pilot Mtns	GM,ST,SR	Geology of the Silver Island Pass quadrangle	24000
Miller, David	USGS	BX	Promontory Mountains	GM,ST,SR	Geology of the Golden Spike quadrangle	24000
Miller, David	USGS	TO	Leppy Hills/Silver Island Mtns	GM,ST,SR	Geology of the Tetzlaff Peak quadrangle	24000

Miller, David	USGS	BX	Northeastern Basin & Range	GM,ST,SR	Geology of the Curlew Valley area	50000
Miller, David	USGS	BX	Northern Utah/Salt Wells Flat	GM,ST,SR	Geology of the Lake Ridge quadrangle	24000
Miller, David	USGS	BX	Northeastern Basin & Range	GM,ST,SR	Geology of the Newfoundland 30x60 quadrangle	100000
Miller, David	USGS	BX	Northern Utah / Black Mtn area	GM,ST,SR	Geology of the Rozel quadrangle	24000
Miller, David	USGS (UGS)	BX	Northern B&R/Terrace Mountains	GM,ST,SR	Geology of the Terrace Mtn. W. quadrangle	24000
Miller, David	USGS (UGS)	BX	Northern B&R/Terrace Mountains	GM,ST,SR	Geology of the Terrace Mtns. E. quadrangle	24000
Miller, David	USGS (UGS)	TO	Northeastern B&R/Pilot Mtns.	GM,ST,SR	Geology of the Miners Canyon quadrangle	24000
Miller, David	USGS	BX	Northern Utah / Black Mtn area	GM,ST,SR	Geology of the Coyote Point quadrangle	24000
Miller, David	USGS	TO	NE Bs&Rg / Silver Island Mtns	GM,ST,SR	Geology of the Graham Peak quadrangle	24000
Miller, David	USGS	BX	Northeastern Basin and Range	GM,ST,SR	Geology of the Rozel Point quadrangle	24000
Miller, David	USGS	BX	Northeastern Basin & Range	GM,ST,SR	Geology of the Hogup Mountains area	50000
Miller, David.	USGS	BX,CA	Northeastern Basin & Range	GM,ST,SR	Geology of the Tremonton 30x60 quadrangle	100000
Morgan, Craig	UGS	GR	Colorado Plat./Paradox basin	PG	Study of the Salt Wash oil & gas field	-0-
Morgan, Craig	UGS	DU,UI	Uinta Basin	PG	Improved compl. tech. in Bluebell field	-0-
Mulvey, W.E.	UGS	GR	Colo.Plat./Moab-Spanish Valley	GM,QG,EG	Geologic hazards of Moab & Spanish Valleys	24000
Mulvey, W.E.	UGS	JU	Juab Valley & Mt. Nebo area	GM,QG	Surf. geo mapping of Nephi seg. Wasatch fault	50000
Oaks, R.Q.	USU (UGS)	CA	Bear River Range	GM	Geology of the Temple Peak quadrangle	24000
Olig, S.S., and others	UGS	TO	Western Utah, Tooele Valley	GH	Quat. earthquakes along Oquirrh fault zone	-0-
Owen, Donald E.	Lamar Univ.	EM,GR	Col. Plat./San Rafael Swell	SR	Large-scale seq. strat. of P,Tr,J, & K strata	-0-
Paull, R.K., and Paull, R.A.	Wisconsin-Milwk	BX,EM,SJ	Basin & Range/Colorado Plateau	PI,SR,SD	L. Triassic conodont biostratigraphy	-0-
Rigby, J. Keith	BYU	SW	Statewide	PI	Fossil sponges of western North America	-0-
Ross, H.P., and others	UURI/U of U/UGS	IR	Escalante Valley/Antelope Rang	GG	Monitoring of Newcastle geothermal resource	-0-
Ross, M.L.	UGS	GR	Northern La Sal Mountains	GM,PT,GC	Geology of the Mount Waas Quadrangle	24000
Ross, M.L.	UGS	GR	Northern La Sal Mountains	GM,PT,GC	Geology of the Warner Lake Quadrangle	24000
Ross, M.L., and others	UGS	GR	N Paradox Bs/Salt Anticline Ar	GM,SR,ST	Geology of the Rill Creek Quadrangle	24000
Sable, E.G.	USGS (UGS)	WA	Southwestern Utah	GM,SR	Geology of the Smith Mesa quadrangle	24000
Sack, Dorthy	Wisconsin-Madis	DA,WE	Northern Utah, Wasatch front	GM,QG	Geology of the Roy quadrangle	24000
Sack, Dorthy	Wisconsin-Madis	DA,WE	Northern Utah, Wasatch front	GM,QG	Geology of the Clearfield quadrangle	24000
Shubat, Michael, and Felger, Tracy	UGS, USGS	JU	Western Utah, Bs & Rg	GM,ST,SR	Geology of the Keg Mountain Ranch quadrangle	24000
Solomon, B.J.	UGS	CA	Northern Utah, Cache Valley	GH	Radon-hazard-potential of the southeastern ..	-0-
Solomon, B.J.	UGS	SE	Central Utah, Sevier Valley	GH	Radon-hazard-potential of Sevier Valley	-0-
Solomon, B.J., and others	UGS	TO	Tooele Valley - Western Utah	GH	Geologic hazards maps of Tooele Valley and ..	24000
Sprinkel, D.A.	UGS	MI	west-cental Utah/Bs & Rg	PG	Petroleum geology of Millard Co.	-0-
Sprinkel, D.A.	UGS	SU	Northern Utah/Overthrust belt	PG	Catalog of wells in Summit Co.	-0-
Sprinkel, D.A., and others	UGS,NIU,USGS	SA	Sanpete Valley/central Utah	ST,SR	Geology of the Christianburg area	200
Sprinkel, Douglas A.	UGS	SW	Statewide	-0-	Devlpmt. of geological info. management sys.	-0-
Stoser, Douglas	USGS	JU	West Tintic Mountains	GM,MG	Geology of the West Tintic Mountains	24000
Tabet, David, and others	UGS	SW	Statewide	CG	Phy.& Chem. characteristics of Utah coals	-0-
Tabet, David, and others	UGS	EM,SE	Wasatch Plateau	CG	Compliation of coal data for Emery coal field	-0-
Tabet, David, and others	UGS	GR	Eastern Utah	CG	Coal & coalbed methane of the Sego coal field	100000
Tabet, David, and others	UGS	GA,WN	Colorado Plateau	CG	Henry Mountains coal field	100000
Tabet, David, and others.	UGS	CR,EM,GR	Wasatch Plateau & Book Cliffs	CG	Resinite resources of selected coal seams of	-0-
Tripp, B.T.	UGS	MI	Basin & Range/west-central Ut	MN	Industrial minerals of Millard Co., Utah	12000
Tripp, B.T. and Blackett, R.B.	UGS	WA	St. George area/southwest Ut	MG	Aggregate resources of the St. George area	24000
Walsh, John, and Foxford, Andrew	Univ Liverpool	GR,SJ	Paradox Bs/Salt anticline prov	GM,ST,SR	Tect./diagenesis assoc w/ Moab-Lisbon faults	-0-
Weiss, M.P., & Lawton, T.	NIU & NMSU(UGS)	SA,JU	San Pitch Mtns/San Pete Valley	GM,SR,ST	Geology of the Wales quadrangle	24000
Weiss, M.P., and Sprinkel, D.A.	NIU,UGS	SA	Central Utah/ Sanpete Valley	GM	Geology of the Manti quadrangle	24000
Willis, G.C.	UGS	SE	Central Utah/B & R Trans. Zone	GM	Geology of the Richfield quadrangle	24000
Willis, G.C.	UGS	GR	Colorado Plateau/Roan Cliffs	GM	Geology of the PR Springs quadrangle	24000
Willis, G.C.	UGS	GR	Colorado Plateau/Book Cliffs	GM	Geology of the Cedar Camp Canyon quadrangle	24000
Willis, G.C.	UGS	GR	Colorado Plateau/Book Cliffs	GM	Geology of the Dry Canyon quadrangle	24000
Willis, G.C., and Higgins, J.	UGS	WA	SW Utah, St. George area	GM	Geology of the Washington quadrangle	24000
Wilson, James R.	Weber St. Univ.	SW	Statewide	MN	Mineral database for Utah	-0-
Wilson, James R.	Weber St. Univ.	TO,UT	Oquirrh Mtns/Mercur Au mine	MN,GC	Geochem. & mineralogical study of southern...	-0-
Wilson, Mark A.	Col. of Wooster	MI	Bs & Rg / Confusion Range	PI,SD	Carbonate hardgrounds in O Pogonip Gp.	-0-
Wilson, Mark. A.	Col. of Wooster	WA	SW Utah/Bull Valley Mountains	PI,SD	Carbonate hardgrounds in J Carmel Fm.	-0-
Yonkee, W.A., and Lowe, Mike	Weber Univ/UGS	WE	Northern Wasatch Mountains	GM	Geology of the Ogden quadrangle	24000
Young, A.	Consult. (UGS)	BX	NW Utah/Grouse Creek Mountains	GM	Geology of the Grouse Creek quadrangle	24000

Meetings and calls for papers

June 15-20 • GSA Penrose Conference - Fractured Unlithified Aquitards: Origins and Transport Processes, Racine, Wisconsin. Contact: John A Cherry, Waterloo Center for Groundwater Research, University of Waterloo, Waterloo, Ontario N2L 3G1, Canada, (519) 888-4516, ext. 2892.

June 16-20 • Dino '94 (the 44th Wyoming Geological Association field conference), Casper, Wyoming. Contact: Tate College Museum, (307) 268-2447.

July 10-14 • Earthquake Engineering Fifth U.S. National Conference, Chicago, Illinois. Contact: Claudia Cook, Newmark Civil Engineering Laboratory, University of Illinois, 205 N. Mathews, Urbana, IL 61801-2397, (217) 333-0498.

September 25-30 • The Society for Organic Petrology, 11th Annual Meeting, Jackson, Wyoming. Contact: Ron Stanton, U.S. Geological Survey, 956 National Center, Reston, Virginia 22092, (703) 648-6462, fax (703) 648-6419.

October 2-7 • Association of Engineering Geologists Annual Meeting, Williamsburg, Virginia. Contact: AEG, Suite 2D, 323 Boston Post Road, Sudbury, Massachusetts 01776, (508) 443-4639.

October 5-7 • ISO 9000. . . Moving Industrial Minerals into the 21st Century, Nashville, Tennessee. Contact: Meeting Department, SME, P.O. Box 625002, Littleton, Colorado 80162-5002, (303) 973-9550, fax (303) 979-3461.

October 5-7 • First Conference on Cordillera Porphyry Copper Deposits, Tuscon, Arizona. Contact: Jim Laukes, The University of Arizona Extended University, 1955 East Sixth Street, Tuscon, Arizona 85719-5224, 1-800-955-8632, ext. 253, fax (602) 621-3269.

October 24-27 • Geological Society of America Annual Meeting, Seattle, Washington. Abstracts are due July 6, 1994. Contact: Meetings Department, 1-800-472-1988, ext. 113, or fax (303) 447-0648.

Cover photo: Bryce Canyon National Park, courtesy of Utah Travel Council. Photo by Frank Jensen.

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